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BOSTON SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

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SOME TROPICAL WHARF CONSTRUCTION

BY T. HOWARD BARNES,* MEMBER, BOSTON SOCIETY OF CIVIL ENGINEERS

(Presented October 15, 1924)

IN volume LXVI of the Transactions of the American Society of Civil Engineers the writer described the construction in 1907–08 of the concrete wharf at Almirante, Province of Bocas del Toro, Republic of Panama.

Studies for other wharves having culminated in their construction it may be of interest to make brief record thereof, together with notes on their maintenance.

(1) At Puerto Barrios, Guatemala, for the International Railways of Central America; in 1910, repairing and widening an existing creosoted wooden approach and adapting the head to conform to an extension (made in 1912–13) of reinforced concrete construction founded on yellow pine piles, with a steel warehouse and shed roofed with corrugated asbestos cement sheets.

(2) At La Union, El Salvador, in 1912–13–14, for the International Railways of Central America; of reinforced concrete throughout, with a steel warehouse roofed with corrugated asbestos cement sheets.

(3) At Tela, Republic of Honduras, for the Tela Railroad Company, in 1913–14; of creosoted yellow pine, with protective

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* Consulting Engineer, 17 Battery Place, New York City.

belts of reinforced cement mortar on the piles over the exposed zone and with a stiffening belt of reinforced concrete along one side and about the head of the wharf.

(4) At Almirante, Panama, for the United Fruit Company, in 1914–15; an extension of reinforced concrete supported by yellow pine piles as in the original, but with some modifications in form and sizes.

(5) At MacKenzie, on the Demerara River in British Guiana, for the Demerara Bauxite Company, in 1919; of green heart piles and other native woods.

(6) At Puerto Cortes, in the Republic of Honduras, for the Cuyamel Fruit Company, in 1919–20; of reinforced concrete piles with floor system of the same, with a structural steel shed.

(7) At Coveñas, on the Gulf of Morrosquillo, Colombia, South America, for the Colombia Products Company, in 1921–22; patterned after the wharf at Tela in Honduras with respect to pile protection.

(1) PUERTO BARRIOS, GUATEMALA

Puerto Barrios is the railroad terminal on the Atlantic Coast of Guatemala. The harbor is fully protected and ample in size. In 1894 a narrow wharf of creosoted yellow pine was built, extending 1,000 feet into the bay, and affording 18 to 20 feet of water at the head. The approach was a single track branching into three tracks at the head, the dimensions of which were about 50 feet by 200 feet.

Foundation. — The sea bottom is a bed of soft ooze, stiffening to a firm resistance after penetration of about 30 feet by a pile under its own weight plus that of a 3,800 pound steam hammer. This condition occasioned doubt at the time of sounding as to the possibility of using concrete, with its consequent dead weight. But reliance was had on ability to secure a sufficient number of long piles from Louisiana and the concrete type was adhered to for the extension.

Decision as to the necessary length of piles was based first on observation of the driving of some repair piles in 1908 and also on the work done in 1910.

In 1910 the head of the old wharf was widened by the use of creosoted yellow pine adapted to give a deflection of 27° to the right, and suitable for track leads to the future extension. At the same time a new berth for shallow draft ships was made by widening the outer stretch of the neck next to the head.

Observation of the destruction by the *Teredos* and *Limnoria* upon the original piles, then sixteen years old, showed the ravages to be largely confined to the zone at or near the surface of the water. This is believed to be due to the frequent turbid condition caused by the silt-bearing waters of two small streams entering near by. This corresponds with observations elsewhere in waters, both tropical and temperate, that marine pests thrive best where turbidity is absent.

The newly driven piles were protected by a belt, about eight feet wide, of yellow metal, with the exception of a score or so for which the belt was of cement mortar laid over poultry mesh and half-driven nails.

The metal used was No. 20 gauge, 40 per cent copper and 60 per cent zinc, applied over ship's felt. In the case of the cement mortar, it was applied by hand over a layer of poultry wire, No. 16 gauge and 1½-inch mesh. Before wrapping the fabric about the pile 16d wire nails were driven half way into the wood at 5 or 6 inch spacings each way, and then bent over, so that the poultry wire should lie outside and not in contact with the wood.

The mortar coat was about ¾ of an inch thick and intended to hold the poultry wire and nail ends completely imbedded in its mass. That this feature was indispensable developed in some instances during driving, when some mortar fell off in patches, revealing the fact that the wire was in such close contact with the wood that the mortar did not get under it. Nevertheless, the possibilities of this kind of protection were demonstrated, and this method was used in the protection of the piles in the Tela wharf. In 1912 the construction of the concrete extension was authorized, and the materials were ordered in January of that year.

Stone and Sand. — A quarry of trap rock was opened at a point six miles up the railroad. The rough stone was loaded

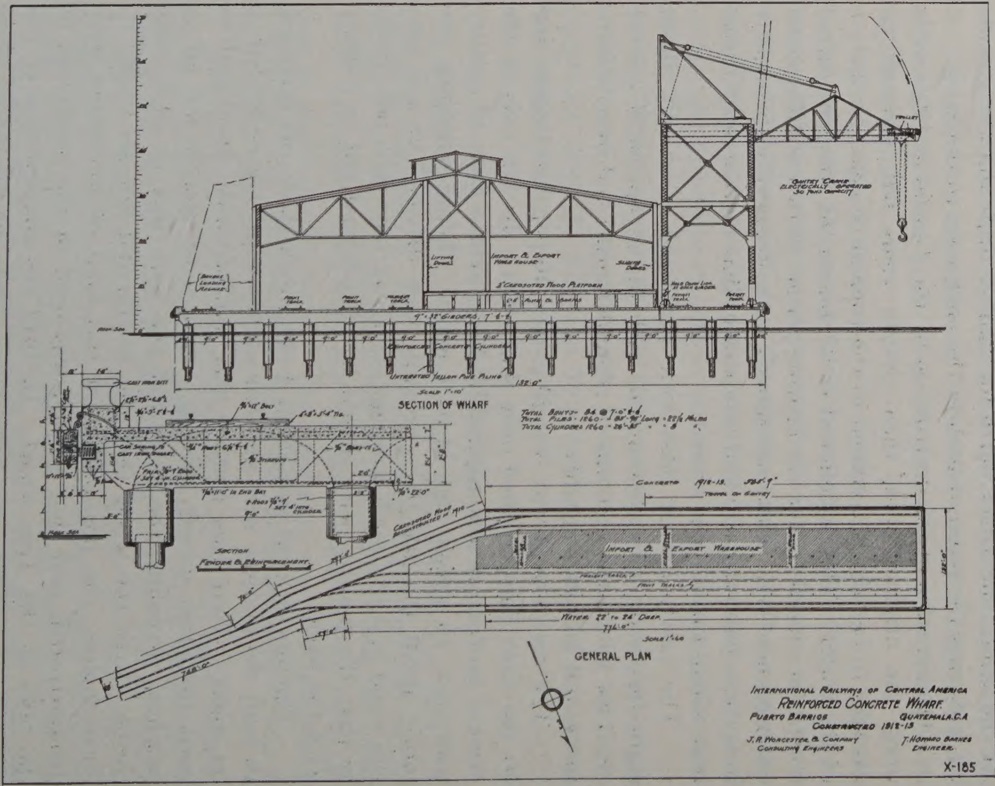

FIG. 1. — REINFORCED CONCRETE WHARF AT PUERTO BARRIOS, GUATEMALA.

into cars from a gravity tipple and brought to the plant for crushing. The sand was of a clean coarse silicious quality and was brought over by boat from a point on the opposite shore of the bay.

Piles. — As in the Almirante wharf, bearing piles of untreated yellow pine were utilized for the foundation. The lengths ranged from 85 to 95 feet, some few being 97 feet long. There was much difficulty in securing suitable sticks, the requirements as to shape and dimensions being exacting. The specifications called for a continual taper from butt to point; points 6 inches minimum diameter; no sharp yanks; no bows greater than the diameter of the pile; minimum diameter at butts 16 inches, and to be hewed down to 16 inches if materially more than that.

A No. 3 Vulcan steam hammer was used in driving. This was mounted on a floating driver built in 1910 on the spot for the work begun that year. The hammer weighed 3,800 pounds gross, the hammer proper being 1,800 pounds with 30-inch drop.

The piles were spaced 7 feet apart in the bents, the latter being on 9 feet centers. The distance remaining to be driven after the hammer weight had taken effect was about 35 feet. The last blows generally produced a penetration of an inch, or sometimes two inches, which was rather large. However, it was estimated from tests made in 1908 that the unusual penetration, 60 feet or more, would develop friction sufficient to carry the proposed loads.

Cylinders. — As shown by the plan the wooden piles were encased by cement cylinders filled with concrete solidly about and over the tops of the piles. These cylinders were made 2½ inches in thickness of shell; inside diameter 22 inches at the head, 18 inches at the points, and length from 28 to 35 feet. A penetration of from 5 to 9 feet into the bottom ooze was thus afforded, and an annular space of 3 inches secured about the pile head for concrete and for planting the reinforcing rods.

The cylinders were reinforced by galvanized triangular wire mesh, of the American Steel and Wire Company, No. 6 wires running longitudinally, crossed by No. 12, all on 4-inch spacings. They were made in steel forms lying on long framed push cars.

The production of the cylinders was the only really difficult part of the whole work, but even this when developed "ran itself".

The outside forms were made in two parts, dividing at the spring line. The lower half rested on the bolsters of the frame and was held steady by movable cradle blocks. There were twenty each of cars and bottom forms. The tops, also the core forms, were ten in number.

In fabricating, all lifting so far as possible was done by chain blocks hung from trolleys running on overhead tracks. Continuous flow in the process was secured as far as possible, the concrete mixing platform being placed at such an elevation as to avoid any lifting to place the concrete, and the stone and sand being supplied by gravity from the bins.

In operation, the bottom form on its car was trundled to the mixing platform and a bed of concrete placed therein. The core form of ribs and sheet metal was then brought in by overhead trolley, lowered into place, centered by blocks and wired down securely. This core was hinged along the bottom line, and made to collapse by sets of toggles attached to a pull-bar. The sheet steel did not meet at the top and the space was filled by a tapering tongue piece of wood about 5 inches wide. This in turn was wedged up to place on the toggle bars and was covered by a strip of paper overlapping the steel. The core was always oiled and the reinforcing fabric loosely wrapped about it previous to being lowered into its position.

When the concrete was placed to the level of the spring line, the top form was trundled over, lowered and bolted to its mate through the outstanding legs of the steel angle stiffeners along the parting line. This form was open at the top for a space about 10 inches wide, through which the remaining concrete was placed.

The concrete was made of cement, sand, stone dust passing $\frac{1}{2}$-inch screen and broken stone passing the inch holes of the screen. The proportions were one, one and one-half, one-half, and three and one-half, respectively. Every means for securing a dense concrete was employed. Constant slushing with thin steel strips accompanied by tapping the outside of the forms with wooden mallets was maintained. This was the one operation where vigilance by the foreman was required. Only when this was faithfully carried out were the cylinders free from air bubbles on the outer skin.

There was a triple track arrangement whereby the newly made cylinder was pushed along on the production track to have the top smoothed up. In the meantime a core-pulling and top-removing gang was operating on the cylinders cast the day before. These were sent back to the plant on the middle track. The cylinders contained in their bottom forms were pushed along and switched back on the outside track toward the unloading point.

The production was nine cylinders per day. Thus the new ones remained on the cars for two full days before being unloaded. At this age they were rolled off on to runs leading to the shore of the bay, whence they were transferred to small deck lighters, three on each lighter, when wanted for placing about the piles.

Thirty-five laborers were engaged on cylinder production: 15 mixing, placing and trowelling; 10 core pulling, etc.; 4 preparing new cores and reinforcement; 6 rolling off, finishing and handling in the yard. The pay roll was about $87 per day for producing 300 lineal feet of product, or 29 cents per foot.

The total number produced and used were 1,260. Roughly, thirty pieces were broken in handling, or 2½ per cent of the whole. About eight days were required for curing the cylinders before placing. Usually much more time elapsed.

Construction. — The cylinders were placed over the piles and pressed down by the weight of the steam hammer, approximately to grade of one foot above high water. They were wedged into a concentric position, pumped out and filled with concrete. Steel bar reinforcement was placed as the concrete filling approached the level of the head. The unit, now presenting the appearance of a huge concrete pile, was then forced by jacks and steamboat ratchets into exact position, for placing the beam and floor forms.

The latter operation, as well as the placing of the concrete, presented no unusual features. Its rapid setting permitted walking and working over it the day following its placing. Forms could be stripped the fifth day, and at times were actually removed the fourth day after the pouring. The concrete mix in beams and floor was 1: 2: 4 of cement, sand and stone passing a two-inch ring.

Fender. — The accompanying plate shows the fender system employed. It is similar to that installed on the Almirante wharf, and has given complete satisfaction.

Warehouse. — The warehouse was finished with a creosoted wood floor at the level of car platforms. It was further arranged to be divided at will into import and export sections by cross partitions formed of rolling steel doors. Thus all imports could be overseen by government officials, and dispatched for the custom house at the capital, or cleared for local points. The saving in expense by being able to discharge steamer freight directly into a warehouse, instead of into box cars as formerly, as well as the saving in sorting and handling of freight, cut the cost into less than half of that formerly obtaining, besides which steamers could be given better dispatch.

It is proper to note in this connection that for freight handling in situations such as this, where every class of product and every size of package has to be dealt with, simplicity is important. Modern ships are expected to be able to lift any article of freight they carry. Reliance is thus had on ship's tackle for putting freight overboard. The function of the shore end is to receive this freight as rapidly as offered. For this, ample platform room made accessible by continuous door openings is required.

In this particular wharf a large part of the export freight is coffee and bananas. For the former, the provisions made have been mentioned, but for the bananas space under the shed for two lines of railroad cars was allowed, and an outboard width of 20 feet in addition for travelling banana-loading machines.

Maintenance. — An examination recently made showed that while the cylinder casings were intact throughout there was some spalling of concrete in the bottom of the floor slab, occasioned by the rusting of rods. . The floor is about four feet above high-water level and gets sprayed daily. Cleaning such exposed rods from rust and cementing over again has been practised. The necessity of extreme care in securing ample cover of concrete for the bars is apparent. It is quite in contrast that no trouble has been noted in the cylinders, which are constantly sprayed or soaked in salt water. Two circumstances are probably responsible for this difference:

First, the reinforcement in the cylinders is galvanized; and second, the exterior surface of the concrete has every opportunity for being inspected. The rods in beams and floor are plain steel and inspection after stripping of forms is less easy. These rods are, moreover, more liable to get moved close to the surface of the concrete, whereas the steel in the cylinders was securely held close to the interior of the cylinder shells, there being no serious disadvantages in its being temporarily exposed on this surface.

Camps. — An interesting feature in the administration, by which method the construction was carried out, was the provision of labor camps. These were made superior to any others available to the men, and maintained in sanitary condition. Large bunk rooms were avoided, each room being occupied by but two men.

All help had to be trained in the special features of this construction and changes in personnel were avoided. These attractive and comparatively cheap living quarters made the men reluctant to forfeit them, and obviated a large labor turnover.

Statistics of Materials, Cost, etc.

Area of concrete floor, 132 by 586 feet		77,352 sq. ft.
Number of piles		1,260
Length of piling at 90 feet each, average		113,400 lin. ft.
Length of cylinders at 32 feet each, average		40,320 lin. ft.
Concrete:		
In cylinders	48,384 cu. ft.	
Filling cylinders	38,556 cu. ft.	
Girders, slab, etc.	65,754 cu. ft.	
Total	152,694 cu. ft. =	5,655 cu. yds.
Warehouse and shed:		
Area		52,000 sq. ft.
Weight of structural material		604,000 lbs.

Total cost, including water and light, $66,263

Costs

		Labor and Overhead	Materials	Total	Per Square Foot
Piles, driving and squaring in place		$13,973	$57,365	$71,338	$0.923
Cylinder making:	Per lin. ft.				
Plant	$0.143		$5,309		
Materials	.382		17,364		
Labor and overhead	.310	$12,484			
	$0.835				
Cylinders:					
Placing		3,258			
Filling		9,029	11,197		
Total making, placing and filling		$24,771	$33,870	58,641	0.760
Concrete in floor and beams:					
Forms		$9,788			
Placing		5,341			
Steel bending and placing		2,376			
Totals		$17,505	36,344	53,849	0.697
Fenders		904	1,204	2,108	0.027
Totals of foundation and floor		$57,153	$128,783	$185,936	$2.407
Warehouse and shed		. .	. .	66,623	
Expended for camps		. .	. .	23,943	
Total expenditure		. .	. .	$276,502	

Cost of overhead and office expense was 52 per cent of total

The work was carried out by administration under the immediate supervision of George L. Mirick a member of the Society, as resident engineer.

(2) La Union Wharf

La Union, El Salvador, Central America, is the terminal on the Pacific of the Salvador Division of the International Railways of Central America. It is situated 9 miles within the Bay of Fonseca, that body of water where El Salvador, Honduras and Nicaragua come together.

The railroad leading northerly to San Miguel was partially constructed by the government in 1902, with wharf projected at Punta Cutuco, a mile and a half down the bay from La Union.

The rise and fall of the tide is about 10 feet, and as the area of the bay is many square miles, the tidal prism has an immense volume, sufficient to cause serious currents at any available situation to be chosen for the wharf.

At Punto Cutuco deep water is found near the shore. Towards La Union, shoal water occurs, until at the city itself an approach of one mile would need to be provided for a wharf located there. Along the shore seaward the depths are less favorable than at Punto Cutuco, and would necessitate more railroad.

Soundings were made in the spring of 1909. A location at Punta Cutuco at once appeared the advantageous site, and detailed soundings were taken at this location. The sea bottom here consists of a gravel lava flow, impenetrable by piling. There is very little overlying silt out to a distance of about 700 feet from the shore, where the lava shelf breaks off. Thence the bottom consists of an ooze underlaid by gravel.

The current at this point is very strong at certain stages of the tide, hence an alignment not seriously diverging from the direction of the current was called for along the berthing spaces.

Construction was ordered early in 1912, and final studies were made with J. R. Worcester & Co. acting as collaborating consulting engineers.

Lay-out. — A new design for the foundation was made. In place of the cylinders at first contemplated, it was planned to use, as far as feasible, 20-inch square concrete piles. These were spaced 10 feet apart in the bents, the latter being on 30-foot centers. It was left to be determined at the time of construction to what extent the pile type of foundation could be employed, and at what point to adopt cylinders. The cuts show the lay-out and the details of construction.

The plant began to arrive in June, 1912, and a camp, water supply, stone-crushing outfit, woodworking plant, store sheds, etc., were erected. Everything was rather more permanently prepared than ordinarily, in view of the utilization of the plant in future construction and operation of the railroad and terminal.

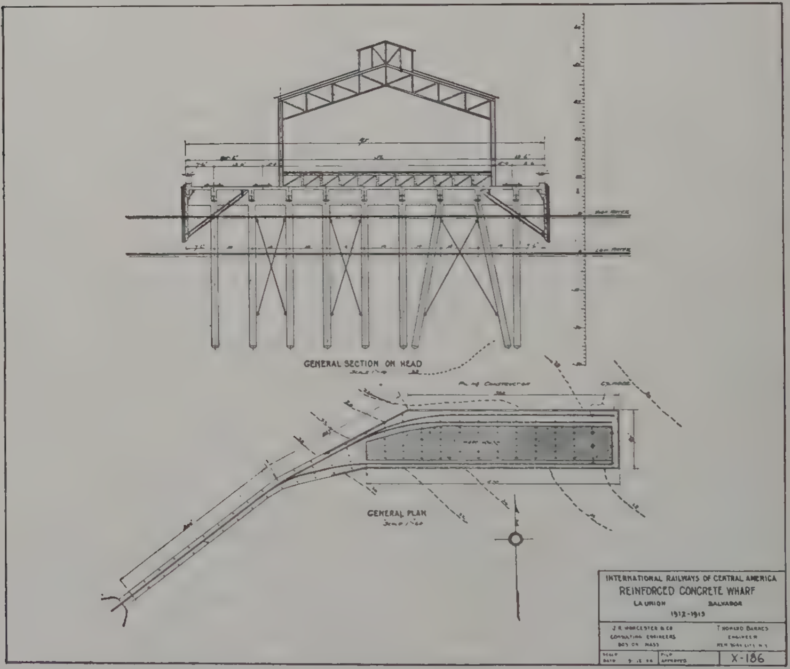

FIG. 2. — GENERAL LAYOUT OF WHARF AT LA UNION, SALVADOR.

Stone and Sand. — Abundant stone of satisfactory texture and suitable size for crushing was obtained along the railroad right-of-way and adjacent lands about 5 miles out, and brought in by trains. Sand was brought in on lighters from adjacent beaches. While not as sharp as might be desired, the sand was clean and free from organic matter.

Labor. — The native peon is a fine worker. Differing from the African, he works with less compulsion and with more snap. At this time one and one-eighth soles (45 cents gold) were the average wage. The work was entirely by administration and nine hours adopted as the daily period, 6 to 11 A.M., 12.30 to 4.30 P.M.

Piles. — The plant comprised a casting floor adjacent to the crushing bins. Forms for casting two piles in one frame were made up. The reinforcement was designed to permit any pile up to 40 feet long being suspended in horizontal position when slung in its center. For piles of greater length two slings were demanded. The toe of the pile was shod with a blunt-pointed cast steel shoe, having a nozzle-shaped core hole in its center. Terminating in this hole was moulded a 2-inch pipe, with its head turned outward from the pile near the top by use of fittings, and used to connect with the jetting hose.

Reinforcement. — The reinforcement of girders and beams was of two distinct kinds, — first, a system of structural shapes permitting passage thereover, as soon as placed, of the travelling erector, which consisted of a stiff leg derrick fitted with swing hoister and having a boom 62 feet long. Supplementary to this system were round mild steel bars apportioned for shear, negative and other stresses, and serving to unite the concrete with the rather large members of the structural system. The floor system was of round bars.

Erection. — In the head of each pile was moulded an 8-inch "H" column, also two heavy eye bolts spaced 10 to 15 feet apart on one of the faces, these to serve for connections for temporary bracing.

A heavy abutment was built, from which the erector started the operation of placing the piles. The neck of the wharf runs 16 feet wide for about 300 feet. The track gauge of the traveller was at first 10 feet, corresponding with the spacing of the pairs of piles in the first bents.

The piles were loaded on trucks standing on a track leading to the shore, where a heavy swing derrick which had been installed for general handling purposes transferred the piles to a deck lighter.

The necessary length of each pile had been carefully determined by sounding with rods. Brought under the erector boom the pile was lifted by a clamp fitting the "H" column on its head. The position of the pile having been fixed, the hose connection to the outstanding 2-inch pipe end was made from a steam pump on the erector platform. With this preparation the pile was lifted and dropped, while water was forced through issuing at the toe. This pumping was continued until the pile had abraided a seat for itself in the rock by the ramming process.

The pile was then guyed into approximately vertical position and settled by blows from an Arnott No. 3 steam hammer — a matter of a half inch or so. Levels on the head were taken and a section of "H" column of suitable length was added, to extend to grade the section cast in the pile head. At the same time the section was drilled for bolting to a pair of 12-inch by 45-pound channels forming the bent cap or girder.

Another pile was then similarly placed, mating with the first and 10 feet away. The pair of channels were bolted on, and a pair of cross-bracing rods fitted with turnbuckles hooked into the eye bolts in the face of the piles.

Next, I-beams 15 inches by 42 pounds were used to connect the abutment and the new bent, and braced temporarily by horizontal cross rods.

This completed the structural part of the steel work, but a second pair of I-beams was temporarily laid down to carry the weight of the traveller from this to the next bent.

Thus progress was made from bent to bent. At the point where the approach widened the stiff leg was spread to a 30-foot base for greater stability.

The wharf was laterally stabilized from this point outward by inclining two piles in each bent. The uniformity in position of the heads of the piles was not changed, but the footing of each inclined pile was made as close to its neighbor as possible.

The pile system of foundation was adhered to until a length of 57 feet of pile (11 tons weight) was required. From this bent, 70 feet from the end of the wharf, concrete cylinders 5 feet in diameter were employed in two bents.

These cylinders were spaced about 25 feet apart in the row, requiring four per bent, or eight in all to complete the foundation. They were built on shore in sections 10 feet long. The walls were 4 inches thick and amply reinforced by galvanized triangular mesh of the American Steel and Wire Company's make. The ends were moulded male and female. For this, cast-iron, machine-turned rings were employed producing plain bevelled grooves and corresponding recesses in the concrete.

For connecting one section with the next, six short-necked eye bolts fixed in channel pieces were moulded in the concrete near the lower rim with the eyes standing inwards. Eye bolts 10 feet 3 inches long, connecting by shackles at the lower end and having a long thread on the other, were used to join the fixed eyes in one section with those in the one above.

The section forming the foot of any cylinder was moulded on a steel plate cutting edge stiffened by a 3-inch angle. A 2-inch jet pipe perforated with $\frac{1}{4}$ inch holes was curved to shape and clamped under this angle.

Sections were floated out on deck lighters and built up to the desired length of cylinder. For the longer cylinders it was necessary to complete the assembly while the lower sections were submerged, otherwise the weight would have been too much for the erector.

Thus formed the cylinders were lowered into the proper place and allowed to sink under their own weight, aided by the water pumped through the foot coil and issuing in small jets near the cutting edge.

The finer material within the cylinder was ejected by a 5-inch suction pump, following which four second-hand 8-inch wrought-iron pipes, coupled to about 40-foot lengths, were driven therein to refusal.

The cylinder was then filled to above water level with concrete placed with a tremie in continuous operation. This method avoided depositing any intermediate laitance, while that formed at the surface was easily disposed of.

Forms were bolted about the heads and the cylinders built up to grade, at which time the structural shapes were set up in position and anchored into the concrete by additional round

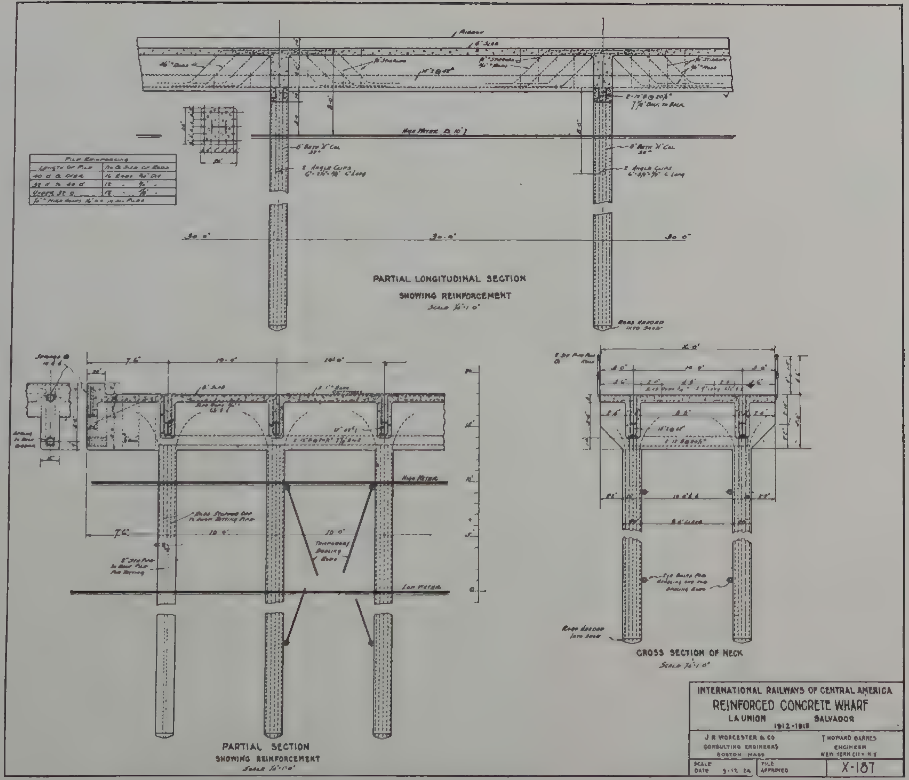

FIG. 3. — DETAILS SHOWING REINFORCEMENT OF LA UNION WHARF.

steel bars. The skeleton of structural shapes was thus continued to the end of the wharf.

Concrete Envelope. — The concreting of the girders, beams and floor was started and maintained a few bents behind the pile and cylinder placing. Forms for the moulds were in part hung from the structural steel and in part supported by pairs of trussed clamps reaching fore and aft from pile to pile.

Fender. — Some difficulty has been had in securing a proper fender system. The hard bottom prevents the usual wood-pile type, excepting in a part of the inner berth. The fenders as originally placed were the suspended type and were only 6 feet deep, made of creosoted wood. They were hung from anchored eye bolts and abutted against car springs working in cast-iron cups set 10 feet apart in the concrete.

Owing to the current small ships were found to be in danger, on a rising tide, of getting under and being held by the bottom of the fender. An attempt to hold wooden piles with iron-shod points was a failure. Ultimately the original fender was widened to about 13 feet and braced against the second line of beams by inclined timber struts hanging in iron stirrups, so as to give slight side movement.

Warehouse. — An enclosed steel frame warehouse was built on the wharf, having a creosoted wood floor at the level of the platforms of cars running on the tracks alongside. The warehouse was intended to serve, as at Puerto Barrios, for both imports and exports.

Maintenance. — Examinations have been made of the condition of the concrete. At last reports no spalling or even rust coloring of the concrete has appeared.

In the piles where deterioration or indications of cracks due to rust formation might be expected, nothing has developed of this nature. The maximum size of reinforcement was $\frac{3}{4}$ inch round bars. A margin of $1\frac{3}{4}$ inches was allowed from outside of metal to the surface of the concrete, and the wrapping with $\frac{1}{4}$-inch wire was faithfully carried out.

Number of piles, 141, equal		5,168 lin. ft.
Labor cost per linear foot:		
Steel placing	$0.183	
Concrete placing	0.094	
Placing piles	0.548	
Total placed	$0.825	
Number of cylinders, 8, equal to		410 lin. ft.
Labor cost per foot:		
Making	$2 33	
Placing	2 16	
Filling	1 09	
Total	$5 58	
The cost of the wharf, excluding the shed, was		$159,000
Area of the wharf		46,900 sq. ft.
Cost per square foot		$3.39

The construction was carried out by administration under Mr. Richard C. Burton, associate member, American Society of Civil Engineers, as superintendent.

(3) Tela Wharf

The port at Tela, Honduras, was created for the shipping of bananas. Up to January, 1915, all fruit was sent out to the ships in lighters, — a method expensive in handling and destructive to the quality of the fruit. The wharf was but one feature in the creation of the terminal comprising a dual railroad system, with shops, and a town with water supply, electric lights, wireless station, etc.

The place does not deserve the name of port, for it is only a roadstead. Its location is a shallow, crescent-shaped dent in the east and west shore of Honduras extending from Cape Gracias to Puerto Cortes, about 40 miles from the latter. Punta Triunfo shields the site from the northeast trades and Punta Sal gives protection from the infrequent squalls from west to northwest. Towards the north over the sector from northwest to northeast no protection is afforded, and from this fact the difficult features of design resulted.

The hard storms, or "northers," as this name indicates, come mainly from that direction. This fact having been ascertained, the wharf was given a direction almost precisely north, so as to expose as narrow a front as possible of either wharf or ship to sea swells and violent winds.

The shore current is almost constantly westerly, hence it was planned for ships to lie on the westerly side of the wharf, although berthing facilities were provided on the easterly side as well.

The minimum depth of water secured at the head, which was 500 feet in length, was 26 feet, the water at the end being 35 feet deep. The sea bottom consists of a very compact silicious sand. In sounding by hand with a pointed rod it was difficult to penetrate over 2 to 4 feet. From this as well as from experience in some driving for temporary landings near by, it was evident that jettings would be required in the driving of the piles so as to prevent splintering.

Materials. — Owing to the absence of materials readily obtainable for a concrete wharf, one of that type was out of the question. There were also other reasons against concrete and in favor of a structure more flexible in its supports. The rigidity in the floor system which reinforced concrete affords would have been desirable, however, since it acts as a huge horizontal beam to give unified resistance by all the piles against lateral pressure.

Creosoted yellow pine piles and timbers were chosen as materials. To stiffen the floor system, a deep built-up timber ribbon was adopted, together with a horizontal reinforced-concrete beam built between one of the ribbons and the adjacent wood stringer. This space was about 2½ feet wide by 14 inches deep, and attachment to the wood on each side was effected by half-driven boat spikes whose heads were thus left free to enter the concrete. A similar stiffening 12 feet in width was carried across the wharf head. For further stiffness the 3-inch flooring was laid diagonally on the entire 500 feet long head of the wharf.

The treatment of the piles was specified to be 18 pounds of creosote to the cubic foot, and of the timbers and flooring, 14 pounds. The specifications for quality of timbers called for practically heart material. For such quality 14 pounds was deemed a sufficient injection of creosote.

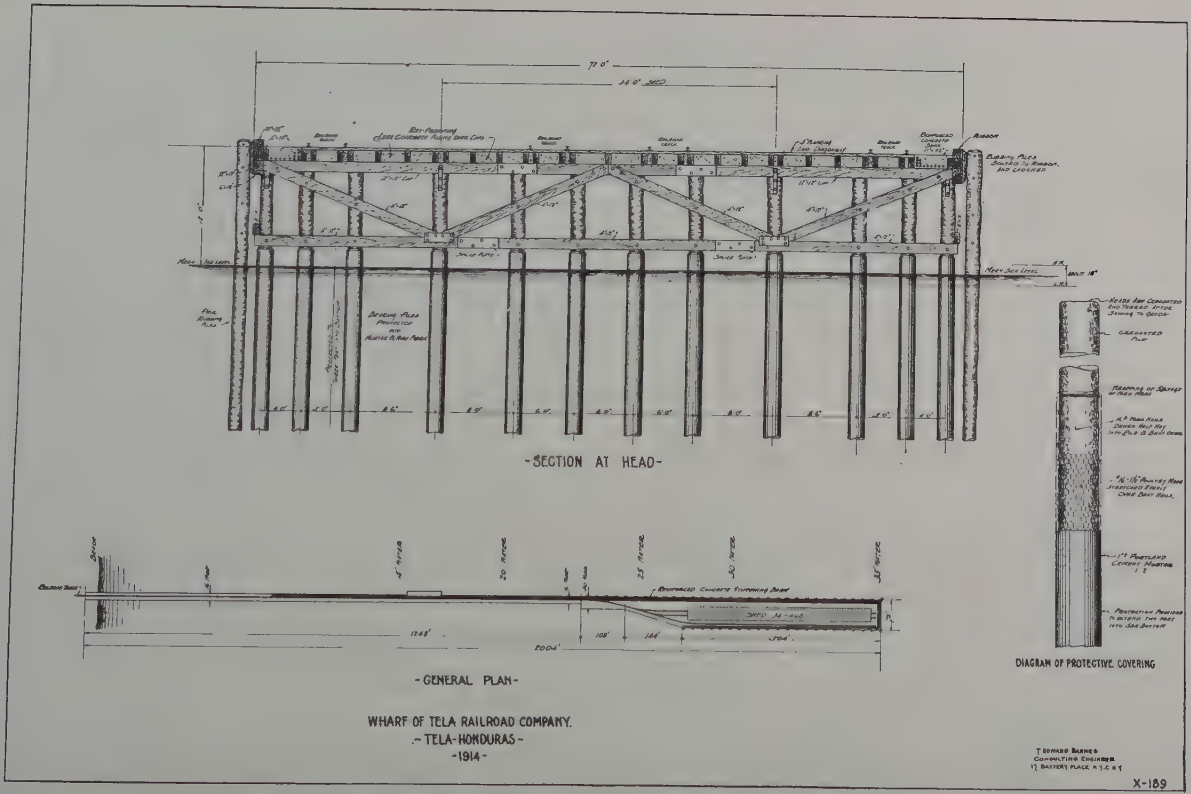
72' 0"
34' 0" SHED
Rot-Proofing Lean Concrete Filling over Caps
Railroad Track
3" Planking Laid Diagonally
Reinforced Concrete Beam
Ribbon
Rubbing Piles Bolted to Ribbon and Checked
12"×12" Cap
Splice Plate
Mean Sea Level
H.W.
About 18"
L.W.
Fire Rubbing Piles
Bearing Piles Protected with Mortar & Rip Rap
-SECTION AT HEAD-
Heads are Creosoted and Treated after Sawing to Grade
Creosoted Pile
1" Portland Cement Mortar 1 : 2
Protection Provided to Extend Two Feet into Sea Bottom
DIAGRAM OF PROTECTIVE COVERING
Beach
Railroad Track
15' Meter
20' Meter
25' Meter
30' Meter
35' Meter
Reinforced Concrete Stiffening Beam
SHED 34' × 448'
1248'
2004'
108'
144'
504'
-GENERAL PLAN-
WHARF OF TELA RAILROAD COMPANY.
-TELA-HONDURAS-
-1914-
J. Howard Barnes
Consulting Engineer
17 Battery Place N.Y.C. N.Y.
X-189

FIG. 4. — WHARF OF TELA RAILROAD COMPANY, TELA, HONDURAS.

Pile Protection. — The *Teredo* and *Limnoria* were not especially active along the coast at this time. Two wharves built of creosoted materials lying east and west within a few miles of this location showed very little attack from marine borers after a life of several years. Nevertheless, it was thought unwise to omit protection of the exposed belt since observation shows that rapid increase of such marine life develops following its first appearance.

The possibilities of a protection consisting of an application of cement mortar over poultry wire had been experimented with on a few of the piles in the construction of the Puerto Barrios wharf in 1910. The condition of this covering in 1913 was so good that all doubts in the writer's mind of its possibilities were banished. Incidentally, it should be recorded that "Yellow Metal" protection used in 1910 had deteriorated, having become very brittle. So evident was this that pure copper was taken as the alternative covering to be chosen in the case at hand. The cost for the copper, valued at that time at 18 cents per pound, would have proved over double the cost of the mortar system, hence the latter was determined upon.

The application was simple. Pairs of rollways were laid at right angles to a service track and level with the car platforms. They were spaced so that the proposed protected zone of the piles should be clear of the lines of support, an arrangement which reduced to a minimum the cost of handling, both in and out of the yard.

Thus placed, 16 penny plain wire nails were driven halfway into the wood over the zone area on spaces 5 or 6 inches apart. The outstanding part of the nail was then bent over by use of a $\frac{3}{8}$-inch piece of pipe, whereby too close contact with the wood was avoided. Poultry netting No. 16 wire by $1\frac{1}{2}$-inch mesh was then wrapped not too tightly about the pole so as to avoid a contact with the wood, and was then wired in place. A coat of one to two cement and sand mortar was then thoroughly applied by hand to the uppermost half of the zone. The following day the pile was rolled half over and the belt of mortar completed. The following day there was applied a 1:3 solution of water-glass in water. The mortar was kept under cover of moistened burlap for several days, preventing the drying out of the mortar and minimizing the oozing out of the creosote and consequent weakening of the fresh mortar. The position of the protected zone allowed for two feet penetration into the sand, and for extending somewhat above the water line.

Pile Driving. — The piles were sunk by aid of a double water jet, 1 inch diameter each, under pressure of a steam pump located on the driver. An 1,800-pound pile cap and 2,800-pound hammer were used. These afforded dead weight while the pile was being jetted to within a few feet of its depth, whence the hammer was utilized until the full penetration of about 20 feet was attained.

The number of piles driven per day was rarely over eight. The pile-driving gang sawed the tops to grade and placed the pile caps, using the winch power to line up the bents. This, of course, slowed up the driving total but accelerated the general work. There was no trouble by loosening of the protective coating in the driving of the 1,100 piles used on the work. No spur or brace piles were driven. The purpose was to leave the entire structure free to yield as a unit against horizontal pressure or shock, and thus save damage.

Timber Work. — Care was used to creosote and tar every pile top and timber cut where the original creosoted surface was molested. The floor beams were not butted but lapped, being for this purpose two feet longer than the double bent span. Four pairs of galvanized iron plates were used on each bent to attach the caps to the piles, besides which steel pins were drifted at each bearing of cap on pile and beam on cap.

Fender. — The fender system consisted of pairs of rubbing piles spaced 24 feet apart along the berthing spaces with a cluster at both corners of the head. These piles had no protective coat for obvious reasons. As heretofore stated, the vessels regularly lie at the wharf on the west side, the prevailing wind and current keeping the craft eased away from contact.

Rat Proofing. — To prevent any harboring of rats the spaces above the pile caps and between the floor beams were filled with lean concrete.

Maintenance. — The only damage to the mortar protective coating has been by floating timbers and was confined to the belt at the water surface, where repairs are easily made. Otherwise, the result has been all that could be desired, and promise is given for a permanence greater than any metal could afford against marine borers.

During the ten years that the wharf has been in use there has occurred about once a year a storm too severe for ships to remain berthed. Once during the construction, and at one time since, damage has resulted to the wharf from storms. At the latter time, said to have been a record breaker, the head of the wharf was somewhat damaged by swells which lifted planks in the floor.

The value of the spring of the wharf as a protection against shock was on one occasion put to a practical test. A steamer of 3,000 tons' displacement came at half speed against the ribbon at about 45 degrees angle. Reliable observers state that the wharf was pressed over about a foot when the ship with her nose gouging into the ribbon came to a standstill, where she stood shivering an instant and then recoiled. The wharf resumed its alignment and the ship was undamaged. The damage to the wharf was the loss of two fender piles and some timbers in the ribbon.

Shed. — There was a train shed erected on the wharf for general shelter purposes. The cargoes being almost entirely of export bananas, no warehousing of imports on the wharf is provided, but such cargo is taken into cars for transfer to the Customs House or storage yards.

Cost. — The final figures of cost are not at hand, but the approximate total was $185,000, exclusive of shed. This is $2.77 per square foot of wharf. The cost of materials and labor per lineal foot for the protective belt on the piles was $0.42. The estimated cost of a protection of copper No. 18 gauge over ship felt, with copper at 18 cents per pound, was $0.99. The difference between this and that actually incurred for the 32,305 lineal feet treated is $18,356.

Distribution of *labor* cost is as follows, overhead included:

Pile driving, including handling from yard, per foot driven 11.9 cents	$9,220
Protective belt, including handling into yard and stacking for treatment for applying protection (cost per lineal foot of belt, 14 cents; application and handling, 22.4 cents)	7,165
Timber work	13,198
Concrete and steel placing	2,830
Shed erection	1,018
Miscellaneous	653
Total	$34,084

The work was carried out by administration under the immediate supervision of Richard C. Burton as superintendent.

(4) Almirante Wharf Extension

The original structure of 1907 provided two berths, each 350 feet in length. By 1913 the increase of business and frequency of ships of greater length made it desirable to add to the structure. Consequently, an extension of 300 feet to the east end was ordered.

Construction was executed in 1914, by administration under Mr. George L. Mirick, member of Boston Society of Civil Engineers, as resident engineer and superintendent. The design was modified in respect to the column sizes, the same being increased from 12 to 16 inches square in section. This increase strengthens the junction point of column and cylinder where formerly some fractures had occurred in the 12-inch columns following shocks from heavy lighters.

Incidentally it is to be noted that the same cylinder forms which were used on the Puerto Barrios wharf were bought and used in the new construction; also, that some cylinders were required 40 feet in length, necessitating piecing of the same under water.

The floor system was also changed by omitting all beams, aside from the ribbon, and carrying all loads by the slab from girder to girder, a span of 10 feet. To this end the slab was made thicker, with corresponding increase in the reinforcement, sufficient to carry the light locomotives utilized on the wharf.

Otherwise no features are to be chronicled other than those noted in the description of the original structure contributed by the writer, and which is published in the Transactions of the American Society of Civil Engineers, Vol. LXVI, 1910.

The writer has a piece of a cylinder of the original wharf taken at the time of the extension, then seven years old. The original skin of the concrete as cast in the steel-lined moulds is unattacked by any chemical action. The waters in this locality are badly infested with both *Limnoria* and the *Teredo*.

(5) MacKenzie Wharf

This wharf is interesting in that native woods were employed throughout, and not for any especial interest in respect to combating marine pests. It is located on the Demerara River, 60 miles above Georgetown, the capital of British Guiana. No enemy threatens other than a possible invasion of ants along the land margin of the wharf.

The location was along the river bank, calling for an outline that would properly conform with tracks about the plant, and at the same time take advantage of all the economies permitted by the contours of the river bottom.

The company had its own sawmill, logs for which were rafted down the river. The region affords many varieties of excellent woods, among which is greenheart, a wood much prized for piling in that zone as well as in England for its longevity.

The design involved no serious construction problems. Vessels alongside were to take the calcined Bauxite by chutes from the storehouse. The tracks were required for incoming freight handling, either foreign or domestic, and for unloading barges of ore transported down the river from the mines, until such time as a railroad should serve for the latter transportation.

The berthing space provided was 800 feet in length. All the piling was of greenheart. Other durable woods were utilized in the floor structure.

At the date of writing the wharf is in active use. During 1923 about 100,000 tons of calcined ore was shipped away, which record will be far outstripped this year.

(6) Puerto Cortes Wharf

It had originally been proposed to erect at this port a structure consisting of a wooden floor system on concrete piles, but on the writer's advice the design was changed to an all-concrete type.

This port is landlocked and had been served with a wharf since the time that the elder Trautwine located the National Railway of Honduras, with Puerto Cortes as a terminal.

The site for the work in hand was occupied by a structure built in 1910, mainly of native wood piling, then in decay. This location made it necessary to maintain freight handling during construction. The formation was a steeply sloping bank running into very deep water, and thus calling for a structure, like the former, parallel with the shore.

It was sought at the start to build up a retaining wall of concrete sheet piling anchored to heavy concrete masses which should form the bases of the warehouse columns. In jetting the sheet piling, however, a thin stratum of silt in the sand deposit was encountered, which caused a slippage, and the plan was abandoned in favor of a pile-supported floor system for the entire structure, and the economy of the first type had to be forfeited.

Design. — The plates show the dimensions of the structure and the details of piles, beams and floor. No further trouble was encountered, although it developed that a heavier hammer would have given greater speed in driving. A jetting pipe was moulded in the center of the piles and water employed throughout in sinking them.

A shed of structural steel was erected on the rear of the wharf floor for the shelter of cars of fruit or of freight. Space on the east end of the wharf is afforded for an enclosed warehouse should that become desirable at any time.

The fender system was the same as that adopted for the original Almirante wharf, which has proved well adapted to a landlocked situation where the rise and fall of the tide is inconsiderable.

As yet no critical examination of the concrete has been made by the writer. The work was executed under administra-

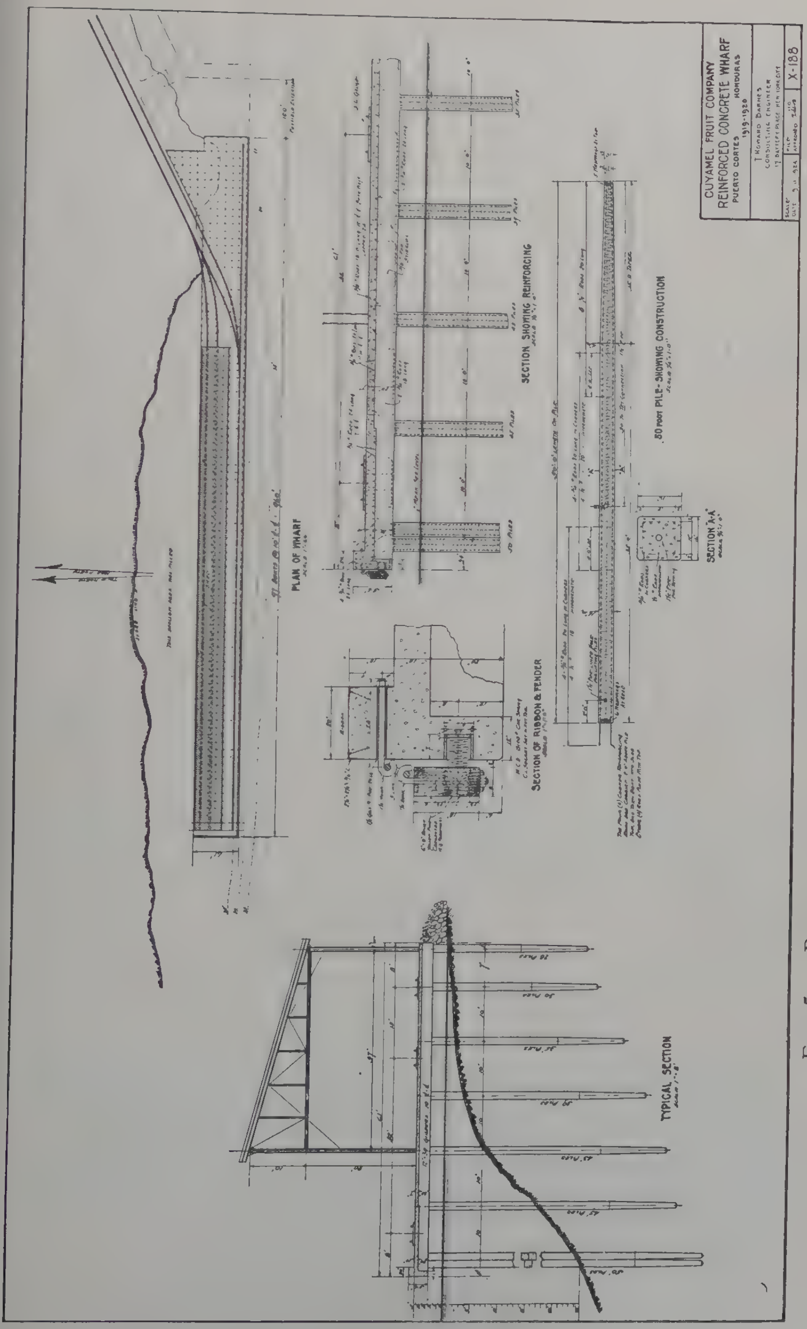
CUYAMEL FRUIT COMPANY
REINFORCED CONCRETE WHARF
PUERTO CORTES HONDURAS
1919-1920
CONSULTING ENGINEER
17 BATTERY PLACE NEW YORK CITY
X-188
PLAN OF WHARF
SECTION SHOWING REINFORCING
50 FOOT PILE-SHOWING CONSTRUCTION
SECTION "A-A"
SECTION OF RIBBON & FENDER
TYPICAL SECTION

FIG. 5. — REINFORCED CONCRETE WHARF AT PUERTO CORTES, HONDURAS.

tion by a superintendent, Mr. Wm. J. Riggs, whose ability had been tested by the writer on similar structures. The piles were of course precast and consequently free from the great doubt as to the condition of concrete when poured under the water.

Cost. — The years 1919 and 1920 were fateful ones in cost of materials. Added to the cost was the difficulty in securing deliveries. At one time a delay of nearly four months occurred, due to shortage of cement.

The unit costs were as follows:

Number of piles	944
Lineal feet of piles	36,942
Area of wharf (square feet)	61,600
Cost of piles (total in place)	$123,090
Bending and placing 305,000 pounds of steel (cents per pound)	1$\frac{1}{16}$
Labor cost making piles (per foot)	$1 62
Labor cost handling and driving (per foot)	$1 70
Cost of beams and deck	$106,521
Bending and placing 262,000 pounds of steel (cents per pound)	0.36
Cost of forms, material	$4,500
Cost of forms, labor	$14,168
Concrete in piles (cubic yards)	2,200
Concrete in deck and beams (cubic yards)	2,400
Total (cubic yards)	4,600
Total cost of wharf, less tools and overhead	$229,611
Cost, allowing 30 per cent for tools and overhead	$298,494
Cost per square foot of wharf, with overhead:	
For piling	$2 60
For deck	2 25
Total	$4 85

(7) COVEÑAS

The wharf at Coveñas was constructed for facilitating shipping from the packing house of the Colombia Products Company. The port has been outlet for many years for thousands of cattle shipped to Cuba and to countries on the Caribbean and the Gulf of Mexico, also to Panama and Peru via the Canal.

It is situated in the Gulf of Morrosquillo, about 60 miles from Cartagena, the principal coast city of Colombia.

The harbor is protected, except from the wind chop kicked up from the northwest. This not being serious the wharf was located so as to require the least length from shore to deep water. The alignment was thus fixed about 20 degrees east of north and required a length of 1,970 feet to secure a depth of 26 feet minimum at the end berths.

Owing to the absence of abundant concrete stone, a creosoted wood type was adopted, with a reinforced mortar protection against marine borers for the exposed zone of the piling. This form of protection has been described fully in the description of the pier at Tela, Honduras.

The interesting point is the manipulation required to prevent undue shattering of the protective material.

The bottom was known to be very hard near the shore, but hand soundings taken further out indicated that sand alone would be encountered below an ooze bed 3 or 4 feet thick. Twenty-five feet of penetration was allowed for in ordering the piling.

A heavy Bucyrus track type driving rig was secured from the Canal Zone and furnished with a steam hammer. The gross weight was about 75 tons, which constituted an immediate test of the bearing power of the piles.

The accompanying plate shows the dimensions and general construction features. Battered piles were driven throughout the length for preservation of alignment. This was thought prudent since the width was only 46 feet at the head and contained only nine piles per bent.

A jetting pipe was used throughout. It was also found necessary to put iron shoes on many of the inshore piles in order to gain sufficient penetration to secure stability.

In a great many of these piles the upper foot or two of the protection was shattered, even with the judicious use of the steam hammer. However, the damage being at or above the water surface the same was readily made good.

It is believed that poultry wire is too low in elastic limit for such hard driving and that the use of a high-tension fabric,

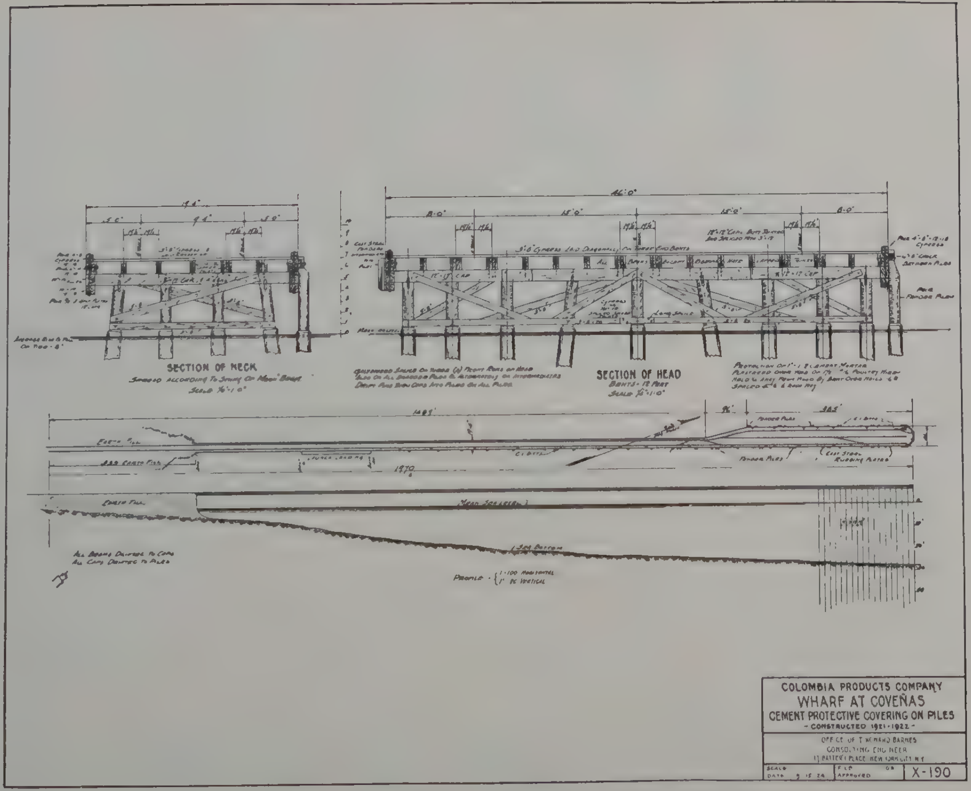

FIG. 6. — WHARF AT COVEÑAS, COLOMBIA.
Cement Protective Covering on Piles.

such as that now on the market for fox fencing, would avoid much of the trouble from shattering at the heads.

The timbering was of close grain yellow pine, treated, as were the piles, with 12 pounds of creosote per cubic foot of wood. The floor was of 3-inch cypress planks, untreated. The fender system consisted in part of piling and in part of cast steel rubbing plates of a convex form bolted to the ribbon and then filled with concrete.

Experience has shown a slight movement of vessels, due to wind chop, and it is believed that a spring fender of the Almirante type would have been preferable for the windward side of the head.

Time has afforded no lesson as yet regarding this protection in this location, but no adverse result is anticipated, since the Tela wharf was six years old when this was started and the results there were, and have continued to be, entirely satisfactory.

The construction work was handled by Mr. Carl O. Riggs.

Costs, etc.

Area of wharf:	
Filled part (square feet)	6,660
Structure (square feet)	55,620
Total (square feet)	62,280
Number of piles	767
Average length (feet)	43
Lineal feet of piles	32,980
Lineal feet of protective belt	19,024
Lineal feet of protective belt (average per pile)	25.1
Labor cost:	
Handling, per pile	$4 00
Driving	6 60
Carpenters' work:	
280 M creosoted lumber (per M)	$26 30
150 M cypress lumber (per M)	18 80
Average of both (per M)	23 70
With overhead (per M)	30 80
Protective belt (per lineal foot)	0 27
Materials for protective belt (per lineal foot)	0 27

Total cost (per lineal foot)	$0 54
Total cost with overhead (per lineal foot)	$0 70
Total cost of wharf	$160,000
Total cost of wharf with local overhead	$181,500
Cost per square foot	$2 93

GENERAL

The summation of experience in fighting marine pests has caused the writer to rely upon properly placed and properly reinforced cement concrete and cement mortar to withstand disintegration by sea water and consequent animal invasion.

In this connection the advice of the late Wm. B. Fuller, member of American Society of Civil Engineers and a member of this Society, given the writer at the inception of the Almirante wharf in 1907, is gratefully remembered, — that, granted a dense concrete using almost any standard Portland cement, one may safely employ it in sea water where there is not danger of abrasion by ice.

The writer would not recommend it, however, unless he were fully assured that high intelligence and conscientious pains were to be applied in its use. It should not be relied upon when poured under water where the sea has constant play on the exposed surface, unless it be a case like the cylinders of the later Colon wharves which were large and placed "in the dry" within tight steel forms.

It is believed that the rock borer described in the "Marine Piling Investigation" by Messrs. Atwood and Johnson, pages 74 and 75, would make no headway against the cylinders of Almirante wharf or any other concrete made as the writer recommends.

MARINE PILING INVESTIGATIONS OF THE NATIONAL RESEARCH COUNCIL

BY WILLIAM F. CLAPP *

(Presented October 15, 1924)

I WILL endeavor to tell you as briefly as possible of the work accomplished in the last few years in the study of the so-called shipworm, and some of the methods which have been used in preventing or alleviating the destruction. I might say, first, that the success which has come from the investigation has been due, to a great extent, not to the biologists or scientists, but to the engineers, because the Committee which was formed to direct the study was composed largely of engineers experienced in organization. The shipworm has been known for centuries, and it has apparently changed but little since recent geologic periods. In historical times it was known to the Romans, who protected their vessels, with some success, by "scupper nailing." In more recent times the damage caused by shipworms in the dykes of Holland was well understood. Here also protection was obtained by "scupper nailing", — the driving of large-headed iron nails into the timbers.

In the last fifty years the studies of a number of independent investigators have added to our knowledge of the shipworm, and previous to the present investigation several score of distinct species have been described, there being but few localities in tropical and temperate waters where one or more species are not found. In 1914 in San Francisco Bay the shipworm was noticed for the first time. The attack gradually increased in severity and in 1920 very severe destruction took place. It has been estimated that in six weeks' time the shipworm caused a property loss amounting to twenty million dollars. This disaster resulted in a local investigation by engineers

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* Biologist, Cambridge, Mass.; Collaborator in the Report of the Committee on Marine Piling Investigations of the Division of Engineering and Industrial Research of the National Research Council.

of that vicinity, to see what had caused the destruction and to find out what could be done to prevent further loss. At the same time, in other places, particularly in the Gulf of Mexico, similar disastrous attacks by the shipworm were taking place, perhaps as great as in San Francisco. In one instance there was supposed to have been a loss of four million dollars in one year through the shipworm, and the original investigation in San Francisco in 1920 became quickly a national investigation. The Committee, first formed in California, sent specimens of the worm to scientists in this country and abroad. I was finally requested to do the biological work for the New York Committee, under the direction of Colonel William G. Atwood. My duty was to examine the worms sent to me and to identify them, for until the identity of the pests was thoroughly understood, a study of methods of prevention would be difficult. There are a number of organisms, all commonly called "shipworms." First there is the large molluscan group generally called *Teredo*, divided into two large genera — *Teredo proper* and *Bankia*. At the time the investigation took place, there were, in the waters surrounding the United States, about nine well-known species belonging to this group of shipworms. Besides the *Teredo* there were two other groups of destructive wood and rock boring mollusks — *Martesia* and *Pholas*. These make up the most destructive mollusks, and all belong to the big group of bivalves or clam-like shells. There are also three groups of crustacean wood-borers — *Limnoria*, *Chelura* and *Sphaeroma*. These are the three particularly destructive crustacea.

As soon as the Committee had been formed under the direction of the National Research Council,* there were immediately placed in 500 different locations in the Atlantic Ocean, the Gulf of Mexico and Pacific waters, test boards designed as traps to catch the marine borers. The construction of these may be briefly described as follows: Pieces of 2 by 4 inch board, preferably of wide-ringed, sappy yellow pine, were sawed into 5-inch lengths (Fig. 1). Twenty-four of these blocks were fastened with brass or copper screws to a board 6 feet long and 12 inches wide. The blocks were marked with small copper tags, numbered from 1 to 24. The board was then weighted and submerged. Every two weeks, after being placed in the water, a block was removed and replaced with a new one. The blocks when removed were sent for examination to the Massachusetts Institute of Technology. By wrapping the test blocks in many thicknesses of paper, it was found that the shipworms and other organisms would survive a journey of ten days or more, arriving at the laboratory in excellent condition for study.

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* "Marine Structures — Their Deterioration and Preservation," by William G. Atwood and A. A. Johnson, the Report of the Committee on Marine Piling Investigations, may be obtained from the National Research Council, Washington, D. C., at $10 per copy.

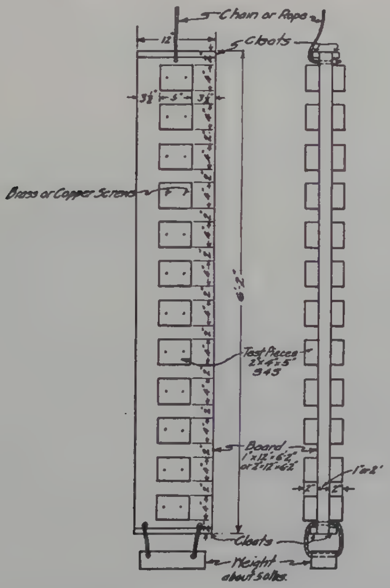

FIG. 1. — SKETCH SHOWING TEST BLOCKS.

In this way it was thought that we could discover what species were causing the destruction in any particular location where the test boards were submerged. In the period of two and a half years, during which the investigation was being conducted by the National Research Council, over 25,000 of these blocks were examined and reported on in the laboratory at the Massachusetts Institute of Technology, the use of the laboratory being given to me through the courtesy of Prof. S. C. Prescott. Instead of nine species, we soon discovered about thirty species of the *Teredo* group, causing the damage in the Atlantic and Pacific oceans and the Gulf of Mexico. We found one of the worst species in our waters to be the well-known *Teredo navalis*. At the time the investigation began it was thought this species was confined to European waters. There had been considerable controversy as to whether the Atlantic coast species was the same as the Pacific. The majority of specialists now feel certain that the European *Teredo navalis* is the same as that found along the Atlantic coast of the United States and also at San Francisco. This species, therefore, has a wide distribution, being found not only in Europe but in this country, from Provincetown, Mass., to the northern part of Florida. The southern tip of Florida, however, has an entirely different fauna, every species of shipworm found on the northern Atlantic coast disappearing on the tip end of Florida. South of Jacksonville, Florida, the shipworms belong to the West Indian and Bermudan group. Three of the latter group are also found in the Pacific Ocean, in the Hawaiian Islands, the Philippines and at Samoa. Previous to this investigation it was thought no species had such wide distribution. We now have six species from the Atlantic Ocean which we know to be identical with the species in the Pacific. It is rather important to know just what these species of shipworms are to be able to identify them, because each has its own habitat. Some cause great destruction and others practically none. The amount of trouble they may cause depends entirely on the number of young. *Teredo navalis* frequently has from one to two million young. Some species, on the other hand, rarely have more than forty young. The latter cause but little destruction. They are rare and it is difficult to find them.

When this investigation started all the collections of shipworms would go in one small-sized cabinet. To show the amount of work that has been accomplished by this investigation, which has been conducted on a more business-like basis than any previous similar scientific study, the collection gathered together could not be stored in one hundred similar cabinets. It is one hundred times larger than all of the previous collections in the world combined. This is due to the efforts of the engineers on the Committee in interesting the railroads and a number of government bureaus in giving assistance by placing test boards on their shore properties and of forwarding the blocks to me with considerable regularity. The amount of literature published since the investigation, with a direct bearing on this problem, has been large, and has resulted in bringing together all that is known at the present time concerning the various borers.

Figure 2 shows the disaster in San Francisco which was the direct cause of the investigation by the National Research Council. This is a portion of the damage which was estimated to have caused a loss of about twenty million dollars and also the loss of several lives.

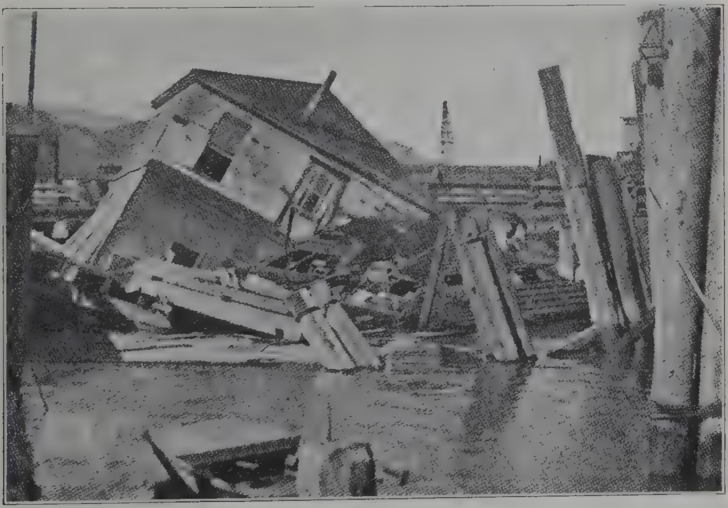

FIG. 2. — MUNICIPAL WHARF AND HOUSE, BENICIA, CALIFORNIA.
Collapsed October 7, 1920.

Figure 3 shows a specimen of one of the common marine borers — a *Bankia*, one of the two big molluscan genera. "Sh" is the shell with which it does its boring, the portion which first enters the wood; "b," the posterior end of the animal, which remains firmly fixed just within the external opening in the wood where the embryo first enters; and "pa," the pallets with which the animal plugs the hole. When enemies irritate the sensitive protruding siphons, or the water becomes too fresh, the animal can plug the hole very tight with these pallets. "Es" are the siphons through which the animal takes its food from the water. When the pallets are withdrawn within the tube the siphons protrude through the hole, one to take in food and water, the other to expel any undigestible matter. When the animal is disturbed the siphons are quickly drawn in and the pallets are pushed out to securely plug the hole. Specimens can remain in this position for several weeks waiting for more favorable conditions. A sudden freshet or a drop in the salinity of the water will cause the shipworm to do this, but it will retain enough salt water within its gills to stay alive for this period, and they have been known to live for thirty days in this way.

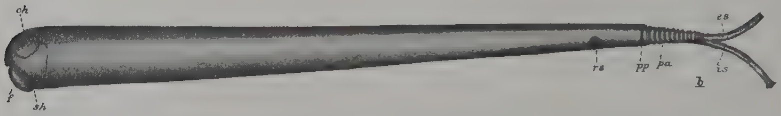

FIG. 3. — BANKIA, A COMMON TYPE OF MARINE BORER

Figure 4 is a reproduction of the left valve of a *Teredo;* "a" is the anterior area, bearing the dental ridges with which the animal rasps off the wood. Strangely enough no matter how widely the species may be removed in other characteristics, these rasping teeth are nearly always identical. At first in the investigation an endeavor was made to determine some distinct characteristic by which means the species might be quickly distinguished, and it was thought that these teeth could be used as a means of classification. Mr. Nelson Fuller made careful photomicrographs of a great number of these very minute rasping teeth of nearly all of the known species. The shell of the largest species is rarely more than 10 mm. in height and there are many thousands of these cutting teeth. However minute the species may be, those teeth, which are used in rasping off the wood, are nearly always just alike in the different species. It makes little if any difference whether individuals are boring into white oak or mahogany or white pine, the cutting teeth remain almost exactly of the same pattern.

The entire classification of the species of *Tereinidæ* is based almost entirely on the pallet. In the *Bankia* the pallet forms soon after the embryo enters the wood and the numerous sections are added as the animal grows. In the *Teredo proper* the pallet starts in the form of an embryonic pallet and keeps its original shape, developing gradually in size as the animal increases.

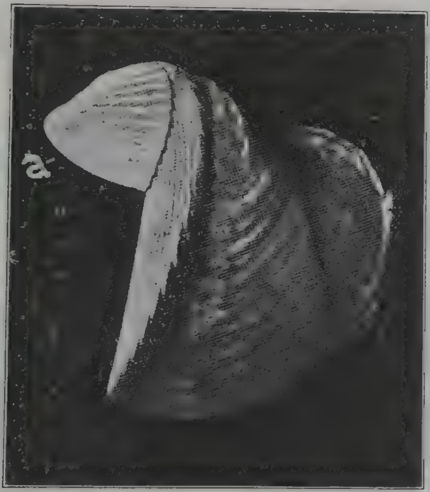

FIG. 4. — LEFT VALVE OF A TEREDO.

"a" — anterior area bearing dental ridges.

By means of the test boards it has been possible to closely estimate the rate of destruction caused by *Teredo navalis*. In ten weeks the tubes will frequently attain a length of 10 mm. Frequently in eight weeks standard size test blocks will be entirely destroyed. Oak blocks 6 inches square and 8 inches long which were submerged for twelve weeks at Galveston, Texas, were entirely destroyed.

Figure 5 shows the surface of wood which has been attacked by the *Teredo*. The small dark spots are the external openings of the tubes. The larger white spots are calcareous barnacle bases. These openings are relatively large, in many cases in firm solid wood the openings are so minute that it is difficult to see them with the naked eye. The tubes of one shipworm will never interfere with the tube of a neighboring worm. If all progress is blocked by the tubes of its neighbors, an individual will not break through into the tube of another but will stop enlarging its tube and remain in that position, living and apparently thriving for a year at least without increasing in size. This leads me to believe that the shipworm does not necessarily need to have wood for food. It has been thought, and much has been published tending to prove, that the shipworm digested and obtained nutriment from the wood it consumed. Possibly this is true, but if a specimen has not progressed for a year, has had no wood to consume and yet is apparently thriving at the end of that period, it seems to prove quite conclusively that it does not need wood to sustain it.

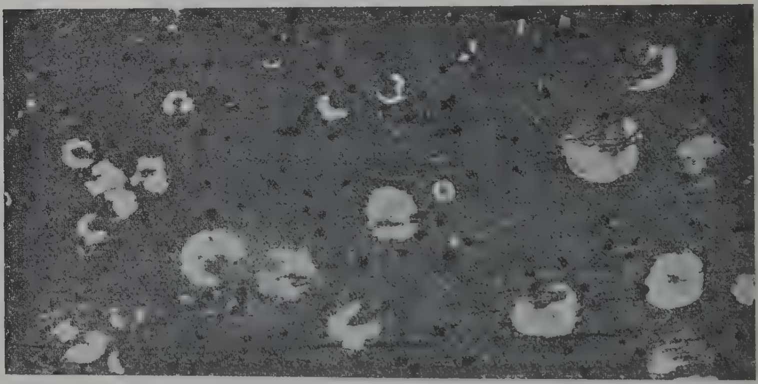

FIG. 5. — SURFACE OF WOOD ATTACKED BY TEREDOS.

Small dark spots are the external openings of the tubes. Larger white spots are calcareous barnacle bases.

The crustacean *Limnoria* always lives near the surface of the wood, eating away thin layers from the surface. It assists the *Teredo* in its destruction, entering the *Teredo* burrow after the original occupant has disappeared, and starting its own burrow there. The *Teredo* will not interfere with the burrow of a *Limnoria*.

On the Atlantic coast the shipworms frequently reach a total length of from sixteen to eighteen inches. On the Pacific coast specimens of *Bankia* have been found with tubes four feet in length.

DISCUSSION OF "SOME TROPICAL WHARF CONSTRUCTION" AND "MARINE PILING INVESTIGATIONS OF THE NATIONAL RESEARCH COUNCIL."

COL. WILLIAM G. ATWOOD:* The paper presented by Mr. Barnes is one of great value to engineers and owners of wharves in harbors infested by marine borers. Records of different types of protection with such clear information as to the methods of construction and their cost are rare. Construction records and inspection reports at intervals furnish the only reliable means of deciding on the relative value of different methods of protection, and they enable the engineer to determine the equated annual cost of such methods. One of the most difficult problems in the study of marine structures just completed by the Committee on Marine Piling Investigations of the National Research Council, of which the speaker was Director, was the securing of just such information as is furnished by Mr. Barnes in this paper. Information that a certain structure was built in a certain year and failed in a certain other year, without details as to methods, materials and costs, gives little data from which to draw conclusions. If more engineers would make their records available, the selection of proper and more economical types of construction could be made much more easily.

One or two remarks in regard to specific structures mentioned by Mr. Barnes may be pertinent. The condition reported at Puerto Barrios, where the marine borers seemed to attack in a narrow belt immediately below low tide, is very unusual. *Limnoria* frequently make their heaviest attack near the low-tide level, but the teredine borers almost universally are the most active near the mud line. The theory that this peculiar condition at Puerto Barrios is the result of turbidity is one in which a number of biologists concur. It may, however, be doubted whether turbidity will always have a protective effect since little is known of the effect on the borers of the various substances which cause turbidity.

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The failure of the yellow (Muntz) metal sheathing used at Puerto Barrios is similar to many others reported from other parts of the world, though a few cases are recorded where this metal has given good service. It seems that it is possible to so manufacture this metal that electrolytic corrosion will not be set up, but in only a few recorded cases has this been done. Muntz metal has generally been placed over a layer of ship felt, as has frequently been the practice with copper sheathing. In the case of copper the speaker thinks that better results might be obtained if the felt were omitted. One case is recorded in Tacoma, Washington, where copper-sheathed piles were unattacked after thirty years service even though holes had appeared in the sheathing. There had been a heavy deposit of copper salts on the piles which apparently formed an efficient protection.

The subject of the protection of timber structures from the attack of marine borers and that of the construction of masonry which would resist the attack of the sulphates in sea water have been live ones for several thousand years, and so far there seems to be no method for securing either result on which engineers as a whole can agree. The use of various methods is too often decided from the standpoint of first cost, and not infrequently because of the eloquence of an enthusiastic salesman. It is clear in the mind of the speaker, as the result of his studies for the last three years, that there are only one or two of the most expensive types of protection for timber which even approach permanency. Masonry structures can be built so that their life will be very long, but unfortunately most of them are not so built.

In order of cost the methods of protection for wooden structures may be classified into coatings, impregnation, and armor, while substitutes such as concrete and metal are still more expensive and durable materials.

Coatings ranging from paints up to a structure built up of wire mesh and asphaltic or bituminous materials give protection for short periods, varying from a few months to a few years.

For temporary structures and structures for the construction of which money is not available in sufficient amount to secure better protection, coatings are the best available method.

Impregnation with toxic or repellant chemicals is efficient so long as the effective elements are not dissolved or leached out by the sea water. Creosote is the most widely used and the most effective material for impregnation, although many failures after short service of creosoted piles are recorded. In spite of its many years of use there is little definite knowledge as to which constituent in the very complicated chemical structure of creosote is responsible for the protective value of this material. It is hoped that the exhaustive series of experiments now being carried on by the American Railway Engineering Association and the United States Forest Products Laboratory may furnish this information and thus make it possible to draw a specification for the best creosote available. Until this information is available the best specification is probably that of the American Railway Engineering Association for No. 1 creosote.

Service records show conclusively that the temperature of the water has a decided effect on the life of creosoted timber. Douglas fir with a 12-pound treatment and yellow pine with 16-pound or 18-pound will give an average of fifteen years' life in the cool waters of the Pacific or North Atlantic, while pine creosoted to refusal (22 to 30 pounds) will not have an average life of over eight or ten years in the Caribbean. In some Caribbean, Gulf and Pacific Island harbors where the *Martesia* is active, creosote impregnation cannot be depended upon to give protection for any considerable time.

Many tropical and subtropical timbers have been from time to time reported to resist the attack of marine borers. Greenheart, such as was used by Mr. Barnes in the MacKenzie Wharf, is one of these, and it has a better record than most of the others. In England and Holland there are several Greenheart structures in good condition after twenty years' use, while the same timber failed completely at Panama in eight years. Some of these failures occurred in practically fresh water, and similar failures in fresh water are reported from the Ganges in India, where there is a species of *Teredo* found in fresh water.

Pile armors, which include fabric and metal sheathing, vitrified pipe and concrete, and cast-iron casings, give sure protection so long as they are unbroken; their value, therefore, is in direct proportion to their durability. Built-up fabric armors are fragile. None of the metals used for sheathing resist corrosion except copper, and this is sometimes torn by boats and floating débris, though if it remain undamaged it is one of the most long-lived armors known. Vitrified pipe is easily broken and is therefore only useful in still water, where floating objects are not likely to come in contact with it. Concrete armor may be built on the pile, as was that described by Mr. Barnes, or it may be built in the form of a pipe or sleeve and placed after the pile is driven. If well made and undamaged it will give good service, though even if as well built as that described in Mr. Barnes' paper it will deteriorate on account of the gradual breaking down of the cement. Cast-iron casings are the most durable and can usually be depended on to give protection for fifty years or more.

Concrete, granite masonry and cast or wrought iron structures if properly designed and built will outlast any timber structures, except perhaps those protected with cast iron casings. Such a result is not however to be depended upon with concrete unless either the Portland cement be improved by the addition of soluble silica or some other cement chemically stable in sea water be used. In this country there has been much less study given binding agents used in contact with sulphate bearing waters than in Europe. In Europe the use of pozzuolana, trass, diatomaceous earth and other materials containing soluble silica with Portland cement is quite general, and in the United States it is practically unknown, with the result that the European structures are more durable.

The high alumina cement manufactured in France is also a material stable in sulphate-bearing waters and has other advantages over Portland cement as well. Its cost, however, is much higher.

The writer agrees with Mr. Barnes as to the general unreliability of concrete poured in salt water, but it should be remembered that the point of greatest chemical attack as well as the usual point of mechanical damage is in the tidal range.

Cast and wrought iron structures have very long life, as shown by the Royal Terrace Pier built of cast iron near Gravesend, England, in 1844, and still in good condition, and the lighthouses on the Florida reefs, built of wrought iron seventy years ago and still in service with a very small maintenance charge. A comparison of service records which appears on pages 159 and 162 of "Marine Structures — Their Deterioration and Preservation" is as follows:

> A comparison of the tabulations of the concrete, cast iron and wrought iron and steel shows 9 concrete structures over forty years old, of which 5 are said to be in good condition; 10 cast iron structures, of which 8 are in good condition; and 5 wrought iron, all more or less corroded but still in service.
>
> Of structures between twenty and forty years old, there are 25 concrete structures, of which 8 have shown practically no deterioration; 7 cast iron, 4 of which are good and 3 have had minor replacements; 12 wrought iron and steel, of which 3 are good and all but one of the other 9 show only a relatively small amount of corrosion.

There have been so few marine structures built in this country which have had long life that an engineer is perhaps likely to overlook the fact that for some structures this long life is not desirable and therefore that a high construction cost is not justified. An engineer should never overlook the factor of possible obsolescence, as more reliable and durable and probably more expensive construction materials become available.

STURGIS H. THORNDIKE:* At the easterly end of the Boston Army Supply Base is a filled area oblong in shape and extending out towards the ship channel like a broad wharf. Before building the pier shed for the navy on this area the filling was enclosed between two bulkheads, parallel and about 250 feet apart, each of them being some 850 feet long.

Reinforced concrete sheet piles, united at the tops by cap beams, were used to form these bulkheads, which were directly exposed on the outer side to sea water, though protected to a considerable measure from blows of floating objects by a wooden wharf construction outside of the bulkhead. The bulkheads were secured against overturning by being tied together at the top. To the cap beams of the piles were fastened long steel tie rods extending completely across the fill and embedded in the concrete framing of the pier shed floor. The piles not only resisted earth pressure, acting as beams held at the top by the tie rods mentioned above and at the bottom by the resistance of the earth into which they were driven, but they also acted as columns subjected to the weight of the outer portion of the pier sheds; hence it was necessary that they be heavily reinforced. In view of the importance of these piles every effort was made to secure a concrete that would be uninjured by the action of the sea water.

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* Of Fay, Spofford & Thorndike, Consulting Engineers, 200 Devonshire Street, Boston, Mass.

The piles were made of a dense concrete mixed in the proportion of 1:1½:3, the coarser aggregate being gravel, and were molded in a horizontal position. The concrete was well rammed until the upper surface was flush with water, this surface then being given a smooth finish before the concrete had set. In driving care was taken to place this specially finished surface on the water side of the bulkhead.

The piles were 18 by 21 inches in cross section, the 21-inch dimension being at right angles to the line of the bulkhead. They were tongued and grooved in order to hold them in line while driving and to make the bulkhead as tight as possible. The corners of the piles were rounded in order to prevent spalling of the otherwise sharp corners.

The piles were cast in the summer of 1918 under rigid engineering inspection, and no pile was driven until it was at least thirty days old. Considerable difficulty was experienced in driving the piles and the excellent character of the concrete was well shown by the resistance of the pile to injury under the driving of the ten-ton steam hammer used.

In January, 1924, a careful examination of these sheet piles was made by a group of engineers, including Colonel Charles R. Gow, Construction Quartermaster of the Base, representatives of the Raymond Concrete Pile Company which fabricated and drove the piles, and members of the firm of Fay, Spofford & Thorndike, designing and supervising engineers. The condition of the piles after five and one-half years of service was found to be remarkably satisfactory. Each of the piles was observed from a motor boat and no pile showed any visible defects. In addition to this general inspection a closer examination was made of certain of the piles, chosen at random, by scraping off the outer layer of oil and mud between high and low water, striking with a hard steel pole the surface thus exposed, and attempting to scratch it with a hard steel tool. The pile surface disclosed after scraping was in each case found to resemble an iron plate and to resist the efforts to scratch it to demonstrate sufficiently that the concrete was at least as hard then as when the piles were driven.

The fact that these piles showed no deterioration during five and a half years is excellent evidence of the resistance that first-class concrete, with a hard smooth surface, offers to sea water.

It may also be of interest to mention, in connection with pier construction, a method of creosoting used for the piles of the State Pier in Portland, Maine, whereby an estimated saving of 80,000 gallons of oil was made through the leaving on of the bark and inner skin for a distance of 30 feet from the tip.

For the unpeeled portion of the pile an allowance of 4 pounds of oil per cubic foot was made, and for the remainder of the pile, 16 pounds per cubic foot. On this basis, assuming the piles to vary uniformly from tip to butt and to conform to specified diameters, there was an estimated saving in oil of 80,000 gallons, which at 12 cents per gallon is equivalent to $9,600.

The saving in cost of labor in not peeling the piles amounted to one cent per lineal foot of pile, or a total of approximately $1,700. This saving was offset to a certain extent by the fact that the bark caused some trouble in the creosoting cylinders. We have, therefore, estimated the total saving in labor due to leaving on the bark as $1,000.

Edward S. Larned: * During the past few years the attention and interest of engineers engaged in construction along the seacoast or in tidal waters have been directed to a study of the behavior of reinforced concrete because of the reported deteri-

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oration of certain structures built under these "exposure" conditions, and it is more important to ascertain the cause of the failure than the mere record of the condition of the work.

It is indeed interesting to note that Mr. Barnes, in his description of wharf construction in the tropics, in a summation of experience dating back fifteen or more years, states that in fighting marine pests he has come to rely upon properly placed and properly reinforced cement concrete and cement mortar to withstand disintegration by sea water and consequent animal invasion. He puts very proper emphasis upon the necessity of using good materials in proper proportions, and executing the work under skilled supervision.

Correct design and a correct specification are of course necessary in any worthy construction, but without skilled supervision and execution they are powerless to prevent partial failures which, under certain "exposure" conditions, may result in ultimate destruction. This applies with particular force to marine construction, and experience shows the necessity of entrusting the execution of this work only to organizations having a personnel of experience and integrity.

In the past few years engineering opinion has become much more conservative in the design of reinforced concrete for sea-water exposure, particularly with reference to the selection of aggregates, proportioning, and the depth of the imbedment of the steel reinforcement. There still remains, however, a wide range of opinion regarding the necessity of adopting the most conservative provisions, which rather emphasizes the personal equation involved in the direction and execution of the work.

The attention of the engineering profession has been very successfully called to the importance of a careful selection, particularly of the fine aggregate, a correct water ratio, and the necessity of scientific proportioning and thorough mixing, as a result of the enormous amount of research and experimental work notably on the part of the Lewis Institute, United States Bureau of Standards, and the Universities of Illinois and Wisconsin, together with the work of various municipal and state boards of public works. Notwithstanding the careful preparation of specification and design, the work is often entrusted for execution to men of little experience, who are unable to secure the results that should follow this careful preparation.

As a result of long experience I am convinced that, so far as the engineering organization is concerned, the most important man in securing the desired result is the inspector or superintendent of construction, and too often we find that men for these positions are selected with a view to salary requirements, and at times from a class almost entirely lacking in appreciation of the responsibilities entrusted to them. The plea of the speaker would be for the training and development of men for this most responsible duty, and for a better recognition of their importance on the part of engineers of perhaps higher rank, expressed in their every-day fraternal and professional relations.

While, as a result of the extensive study of sands, we are impressed with the importance of a scientific selection and grading, still on a wide variety of work we resort to empirical proportions of cement, sand and stone, taking the sand furnished by the local market and basing our acceptance of it upon comparative tests for strength with our standard laboratory Ottawa sand; and providing our proportions are sufficiently rich in cement, we get a very satisfactory concrete for the great majority of work. But for concrete exposed to sea water, or in fact to fresh water, it is highly important that we consider what these empirical proportions mean as affecting not only the strength, but the density and impermeability of the concrete.

The importance of a proper consistency, which is influenced not alone by the water content but also by the fine aggregate and the relative size of the coarse aggregate, is recognized; yet, unless under absolute control by the use of the slump test or flow table, we find too great a variation in the results which could and should be corrected. Indifference on the part of the inspector or contracting force is primarily responsible for this condition.

Let us for a moment consider the unit of measure of the cement content. The proposed standard specification of the Joint Committee assumes one bag of cement, 94 pounds net, to be 1 cubic foot, and there are specifications in force today that consider the barrel anywhere from 3.5 cubic feet to 4 cubic feet.

Many years ago, when Mr. Howard A. Carson began the construction of Boston subways, he determined the cubical contents of American, English and German cement barrels, and, as I recall the figures, found the American cement barrel to be slightly the largest and to contain a little less than 3.5 cubic feet between heads. It was a very common practice in those days to use the cement barrel as the gauge for sand and stone. It should be remembered that the cement barrel of today, although subdivided into four cotton or paper bags, is the same cement barrel of twenty-five years ago, and still we find so important a body of engineers as are included in the Joint Committee calling the barrel today 4 cubic feet.

Engineers very commonly look upon a barrel of cement as containing either 3.5 cubic feet or anywhere up to 4 cubic feet of cement, but under the standard specifications for cement the manufacturer is allowed a residue on the 200-mesh sieve of 22 per cent. This residue and something more below this size has not been reduced to the degree of fineness required to combine with water and set hard in a crystaline mass, — in other words, if the residue on a 200-mesh sieve is mixed with water, it will not set up.

This residue, which is nothing other than fine-ground clinker, might serve to reduce the voids somewhat in certain sands but would not act as a binder, so when we are designing a concrete of the greatest density and impermeability, should we not take this into account in fixing our sand proportion?

For the purpose of showing what this would mean in certain popular fixed proportions, let us assume that 25 per cent of the contents of the cement barrel is inert as a cement binder, and that the barrel does actually contain between heads 3.5 cubic feet in volume, it would then follow that the actual cement of binding value would amount to 2.625 cubic feet per barrel, and the more or less popular proportion of 1 cement to 1.5 sand (based on 4 cubic feet per barrel for sand) would then mean 1 cement to 2.28 sand; the 1 to 2 mortar would become 1 to 3.05; the 1 to 2.5 mortar, 1 to 3.8; and the 1 to 3 mortar, 1 to 4.57.

Average commercial sand may be considered to contain not less than 35 per cent voids, and there is doubtless a great deal of sand used that will run nearly up to 50 per cent voids, so it seems to the speaker that in concrete designed for sea water above mean low tide level, or for fresh water within the limits of the rise and fall of the water level, we should not attempt a mortar mixture leaner than 1 cement to 1.5 sand, and this might be varied slightly following the determination of sand voids, giving due consideration to an increase in these voids on account of excess water content. It might be more impressive, when expressing concrete proportions, to say, instead of 1 part cement to 2 parts sand to 4 parts stone, 1 barrel of cement to 8 cubic feet of sand to 16 cubic feet of stone, if the barrel unit of measure is to remain 4 cubic feet.

There appears to be no danger to plain concrete below mean low water and little danger above this point if care is exercised in the selection of aggregates, proper proportions and a proper consistency used, and if care is taken in the placing of the concrete, but this cannot be said to be the fact in reinforced concrete, and for work of this class the utmost caution is required. The danger lies principally in the corrosion of the steel reinforcement, and the suggestion of one of our leading engineers, who has had a wide opportunity for observation and examination of old structures, is that the steel should have an imbedment of not less than 4 inches from the side of the concrete exposed to sea water above mean tide. Galvanized reinforcement seems to have been entirely free from this trouble, and perhaps with the recognized need of steel for this use, the metallurgist will produce rustless steel possessing also the other required qualities.

LEWIS E. MOORE: * It might interest those present to know that in Seattle Harbor the trestles of the Great Northern Railway, with untreated piles, have been eaten away in five months, and they renewed them at that time interval.

As I read the advance copy of the paper I was struck by the use of Muntz, or yellow metal, the composition being given as 40 per cent copper and 60 per cent zinc. Of course this is one of the brass alloys. It occurred to me in reading it that it would be rather dangerous to put much money into that type of protection, because an imperfect alloy would result in galvanic

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action, particularly in salt water, which would result in rendering the protection useless.

The shipworm has been known for many hundreds of years. All shipwrights had their troubles with shipworms because they ate the ships very soon, particularly those engaged in the tropics or West Indies. The method of protection was with copper sheathing on the bottom of the ships, which was effective as long as the copper remained intact.

In reading up on this subject I came across a record of a pier which is doubtless familiar to Colonel Atwood, although I don't remember where it was — I think in some California Harbor. Here the piles were protected by sheet copper nailed around them from a point a few inches below the mud line to a point at least above high water. After about thirty-eight years the pier was removed and the piles found to be in perfect condition. Some of them were afterward redriven in another place.

The use of wrought iron or cast iron is rather interesting. One example of wrought iron occurs to me in connection with the Slades Ferry bridge in Fall River, in which the piers are cylinders approximately $\frac{3}{4}$ of an inch thick, of wrought iron, and filled with concrete. Those were built in 1874, and the cylinders are still in very good condition though there are some few signs of corrosion.

As Colonel Atwood mentioned, there are really a great many possibilities in the use of cast iron as a protection. It is a substance that lends itself peculiarly well to such a use, because from its very nature its exterior is coated with a shell of hard metal, much harder than the interior, as most of you who have worked in cast iron realize. Consequently, it is well adapted to resist corrosion. It might be possible to design a cast-iron pile, not using it as a cylinder to be sunk and filled with concrete, but filling it with concrete and driving preferably by water jet wherever possible, because it always seemed to me rough treatment to drive concrete or cast iron with a hammer. Where there is a rather sandy bottom, piles of that nature could be sunk by water jet, and I think they would form a very good foundation and one that should be dependable.

H. S. Wright:* I should like to call to Colonel Atwood's attention a concrete structure in sea water which he may not know about. It is a concrete ship (The Polias) wrecked on Cilley Ledge off the coast of Maine in 1920. The coverage of the steel was only ¼ to ½ inch. I had the pleasure of going aboard that ship and inspecting it rather carefully about a year ago. The outstanding feature was that on the lee side, where it did not get the full force of the heavy sea, there was practically no exposure of the steel; no indication of rust. On the weather side for a distance of perhaps 60 feet aft from the cutwater the steel was exposed in spots, and rust streaks marked the location of practically all the other bars of the outer mat. The ship lies well out of water at all tides on a submerged ledge, about 2½ miles off shore, and is rigidly held fore and aft by the ledge. The location is one of the most exposed on the north Atlantic coast. In this concrete vessel the mix was rather peculiar, — I believe it was 1 cement to ⅔ parts clean sand and 1⅓ parts gravel from New York Bay.

Colonel Atwood: I knew that ship was there but had heard no discussion of it. These ships were very interesting pieces of work on the whole, but from the standpoint of a harbor structure we wouldn't expect any deterioration in so short a time. In Europe they use much less cover over their bars than we do and their life is about the same.

The structure, covered with copper sheathing, which Mr. Moore mentioned, was in Tacoma.

The theory that the *Teredo* will not cross a crack is a very common one, but has been proven to be incorrect by the experiments of the Committee. I have known an instance where a *Teredo* crossed a crack slightly over ¼ inch wide.

Mr. Thorndike: I should like to ask Colonel Atwood what his opinion is of that film of oil and mud, etc., that occurs in Boston. It seems to be pretty effective as a protective coating.

Colonel Atwood: I think it probably does have some protective value. I wouldn't say, though, that it would be permanent. I think the sulphates will get through it in time. The

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* Field Engineer, Portland Cement Association, 14 High Street, Boston, Mass.

French have been experimenting recently with a pitch coating with which they frequently paint their concrete above low water. The Chief Engineer of the Department in the south center of France told me this year that they were quite encouraged with the results. So a surface coating of that nature does give some protection. The method being used at Los Angeles now is perhaps still more interesting. They cast a concrete pile and then give it an asphalt treatment similar to the open tank treatment of timber. There is some question whether it doesn't crack the pile on account of the coefficient of expansion of the reinforcing being greater than that of the concrete. When asked, they admitted that it sometimes did but stated that the cracks closed up again when the pile cooled off.

HENRY S. ADAMS * (by letter): The paper presented by Mr. Barnes is most interesting and instructive: interesting in that it tells of foreign countries and conditions, instructive in that it gives facts and figures, explains conditions and problems, and states the reason for the choice of the particular type of structure for each locality.

The only wharf built on wooden piles without protection from Marine Borers mentioned was at MacKenzie, British Guiana. The only place on the North Atlantic seaboard which is free from Marine Borers, so far as the writer knows, is the harbor at St. John, N. B. This is probably due to the large amount of sediment in the harbor water brought down by the St. John River, and kept in suspension by the currents caused by the high range of tides.

Evidence of live *Teredo* and *Limnoria* have been observed at Portland inner harbor; Portsmouth outer harbor; Rockport; Gloucester; Salem; Boston inner harbor as far up as the bridges; Constitution, Lewis, Commercial and Long wharves; the Metropolitan Coal Wharf; Summer Street, South Boston; Spectacle and Rainsford islands; Plymouth and Provincetown harbors; Cotuit and Falmouth harbors; Woods Hole; and all along the shores of Buzzards Bay and New Bedford harbor. Many of us recall the two serious accidents here in Boston due to wharf failures caused by the combined action of *Teredo* and *Limnoria*, namely, at the Fitchburg Station and at Commercial wharf. Many of the failures of sea walls during recent years are due to the destructive action of *Limnoria* upon the piles under the walls, as for example, the wall at Lewis Wharf, north dock. At Long Wharf it is necessary to have periodic examinations made of the wall foundations by divers, and clay and mud placed under the walls to protect the pile foundations.

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* Consulting Engineer, Ames Building, Boston, Mass.

During the past ten years the use of creosoted pine piles in substitution for oak piles has been adopted by the writer for two reasons: one, the resistance offered by the creosote to the depredation of the Marine Borers; the other, the longer life from decay of the creosoted piles, as compared with the southern oak piles that are now the only oak piles available in the market. Some of the wharves recently built with creosoted piles are the Revere Sugar Refinery at Charlestown, Mass.; the Metropolitan Coal Company of East Cambridge, Mass.; and the coal wharf of the Pocahontas Fuel Company, Inc., at Portland, Maine. At the present time the Pocahontas Fuel Company, Inc., is rebuilding another portion of its wharf with creosoted piles and timber.

The State Pier at Portland, Maine, for which Fay, Spofford & Thorndike were the engineers, is built on creosoted pine piles. The Long Wharf outfall sewer at Portland, Maine, also is being built on creosoted piles. The usual treatment is 16 pounds of creosote oil per cubic foot for piles, and 12 to 14 pounds for timber. A wharf with creosoted piles and timber costs from 25 to 33 per cent more than oak piles and untreated timber.

The use of concrete in sea water especially north of latitude 41° has been much discussed. There are many examples of the failure of concrete in sea water all along the coast from Halifax, N. S., to Fore River, Quincy, Mass. These failures are explained in various ways by the interested parties. Some of the causes given are wave action, chemical disintegration, physical disintegration due to freezing, poor sand, poor or insufficient cement, too much or poor water, wrong proportions of aggregate, porous concrete, etc.

There are, however, examples of concrete in sea water which are exceptional and prominent because the concrete is standing up all right. The most notable locally is the reinforced concrete sheet piling bulkhead around the Army Base at South Boston. This bulkhead last spring was as perfect as when driven in 1917 or 1918, and showed no evidence of disintegration in any way. The main reasons given for the durability of this bulkhead are a selected aggregate properly graded to secure a dense mixture, a proper and carefully tested cement, the use of a minimum amount of water, and extreme care in the mixing and placing of the concrete.

The Pocahontas Fuel Company, Inc., is having a reinforced concrete sheet pile bulkhead constructed at its wharf at New Bedford, Mass. This concrete bulkhead is for the purpose of protecting a 12-inch hard pine bulkhead which was built in 1917, but which is being rapidly destroyed by the *Teredo*, assisted by the *Limnoria*. The concrete sheet piles are 42 feet 3 inches long, 18 inches wide, and 16 inches thick. The aggregate is from local banks and is composed of screened gravel $\frac{3}{4}$ of an inch and under, and sand. The fineness modulus of the sand is 3.29, of the gravel 7.75, and of the combined aggregate 5.16. By water tests the voids in the sand are 33 per cent, in the gravel 42 per cent. The normal mixture is $1:1\frac{1}{2}:3$. This ratio has been varied somewhat, but the ratio of 1 cement to $4\frac{1}{2}$ aggregate has been maintained with the result that the concrete produced will absorb in a seven-day immersion test only 3.36 per cent of water by weight. The reinforcing steel is placed 2 inches from the outside of the piles. The concrete sheet piles will be capped with a reinforced beam connected by means of reinforced concrete ties to concrete "deadmen". The portion of the pile extending above extreme low water has been waterproofed, and the concrete beam above the piles will be encased in 2-inch creosoted plank as a protection from freezing, ice, and wave action. The top of the concrete beam will be just below mean high water. The cost of this bulkhead will be approximately $175 per running foot.

The writer, although putting in a reinforced concrete bulkhead at New Bedford, is a firm believer in stone walls for permanent construction in sea water, where the walls can be founded directly on the clay, as in the case of the Fish Pier at South

Boston; or on piles cut off below the level of the proposed dock, as in the case of the Revere Sugar Refinery wharf at Charlestown and at Lewis Wharf in Boston proper; or where the pile foundation can be protected by filling and riprap, as in the case of the walls now being built for the Salem Terminal Company at Salem, Mass.

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BOSTON SOCIETY OF CIVIL ENGINEERS

FOUNDED 1848

PROCEEDINGS

MINUTES OF MEETINGS

BOSTON SOCIETY OF CIVIL ENGINEERS

BOSTON, October 15, 1924. — A regular meeting of the Boston Society of Civil Engineers was held today in Chipman Hall, Tremont Temple, and was called to order by the Vice-President, Richard K. Hale, at 7.30 P.M. There were about 100 members and guests present.

The minutes of the previous meeting were approved as read.

It was voted that the Board of Government be authorized to use the income from the permanent fund for the current year to such an extent as they deemed necessary in payment of the current expenses of the Society. This vote was also passed at the meeting on September 30, 1924, but in accordance with the By-Laws an affirmative vote by the Society at two successive regular meetings is necessary to authorize such action.

Mr. R. K. Hale, Vice-President, stated that an Affiliation meeting had been planned for Wednesday, November 19, 1924, at which Mr. E. J. Mehren, Vice-President of the McGraw-Hill Company, would speak on "The Economic Outlook in Europe." In accordance with a recommendation from the Board, it was voted that the Society omit its regular November meeting in order to take part in the Affiliation meeting.

Mr. Hale then introduced Mr. T. Howard Barnes, Consulting Engineer of New York City, who gave an illustrated talk on "Tropical Wharf Construction," describing some of the work which he had done in South and Central America.

Mr. William F. Clapp presented a brief résumé of the "Marine Piling Investigations" which had been carried out by the National Research Council. Mr. Clapp had charge of the biological studies in connection with this investigation. He described the general work of the committee which prepared the report and showed slides of the marine borers and their destructive action.

Col. William G. Atwood, Consulting Engineer of New York City and a co-author of the special report on "Marine Piling Investigations," outlined those features of the report dealing with the types of pile protection which are in current use.

Mr. S. H. Thorndike presented a brief report of an inspection recently made of the bulkhead at the South Boston Army Supply Base, built of reinforced concrete piles in 1918. Mr. E. S. Larned discussed the precautions which should be taken in marine concrete construction, stressing particularly the need of careful choice of the materials and the need of thorough inspection and supervision on work of this character. Mr. L. E. Moore discussed briefly Mr. Barnes' paper and told of instances of marine pile destruction and of precautionary measures which had been adopted. Mr. H. S. Wright of the Portland Cement Association told of his recent inspection of a concrete ship wrecked some time ago off the coast of Maine.

At the conclusion of the discussion, a rising vote of thanks was given to those, not members of the Society, who had presented papers.

The meeting adjourned at 9.45 P.M.

J. B. BABCOCK, *Secretary.*

DESIGNERS SECTION

BOSTON, October 8, 1924. — The regular October meeting of the Designers Section of the Boston Society of Civil Engineers was called to order by Chairman, Edward H. Cameron, at 6.15 P.M.

The report of the May meeting was read and approved.

The report of the Committee on Prizes was read by its Chairman, Erwin Harsch, and approved.

The report of the Committee on Committees was read by its Chairman, Scott Keith, and approved.

The Chairman introduced Mr. A. J. Blackburn, Architect, Maintenance Department of the Boston Elevated Railway, who spoke upon "Boston's New Car Repair Shops at Everett." Mr. Blackburn described in detail the layout and special features of the new shops and illustrated his talk with pictures of the old and new shops.

Mr. A. L. Nelson, of the firm of Jackson & Moreland, described the illumination problems of the shops, and Mr. G. W. Allison, of Simpson Bros., told of the construction difficulties of the job.

There were 53 members and visitors present.

The meeting adjourned at 8 P.M.

WALDO F. PIKE, *Clerk.*

APPLICATIONS FOR MEMBERSHIP

[November 15, 1924.]

THE By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of twenty (20) days from the date given.

For Admission

Baratta, Edmund Anthony, Everett, Mass. (Age 21, b. Everett, Mass.) Graduate of Everett High School and now a senior at Northeastern University. Refers to H. B. Alvord, C. S. Ell, J. W. Ingalls, W. E. Nightingale.

Bertini, George Eugene, Everett, Mass. (Age 21, b. Boston, Mass.) Graduate of Everett High School and at present a senior at Northeastern University. Has worked for Daniel W. Hyde, civil engineer and surveyor, for two years. Refers to H. B. Alvord, H. A. Buck, C. S. Ell, J. W. Ingalls, W. E. Nightingale.

Bowers, Moses Leo, East Boston, Mass. (Age 21, b. East Boston, Mass.) Is at present a senior at Northeastern University, and worked as detail draftsman for the American Architectural Iron Works during the summer of 1923. Refers to H. B. Alvord, C. S. Ell, J. W. Ingalls, W. E. Nightingale.

Britt, Francis Vincent, Cambridge, Mass. (Age 19, b. Somerville, Mass.) Is a junior at Northeastern University. Refers to H. B. Alvord, C. S. Ell, J. W. Ingalls, W. E. Nightingale.

Coolidge, Ray L., Cambridge, Mass. (Age 42, b. Cambridge, Mass.) Graduate of Webster Grammar School, and two years at Rindge Technical School. 1901–02, rodman for City Engineer of Cambridge; 1902–03, draftsman for Metropolitan Water Works, Boston; 1903–22 transitman for City Engineer, Cambridge; 1922 to date, assistant engineer for City Engineer of Cambridge, present work consists of general office work in charge of preparation of plans, estimates, etc., and a large amount of survey and plan work, with court attendance for the legal and police departments. Refers to H. T. Burrage, L. M. Hastings, G. F. Hooker, C. A. Mason.

Davis, Edgar W., Cambridge, Mass. (Age nearly 36, b. Cambridge, Mass.) Educated in the schools of Cambridge. In 1904–05 was rodman in Cambridge engineering department; 1906, transitman; and in 1910, assistant engineer in charge of sewer work. Since first of this year has been in charge of all outside work. Refers to H. T. Burrage, L. M. Hastings, G. F. Hooker, C. A. Mason.

Frost, Daniel Carter, Newburyport, Mass. (Age 20, b. Holliston, Mass.) Is a student at Northeastern University. Refers to H. B. Alvord, C. S. Ell, J. W. Ingalls, W. E. Nightingale.

Frye, Harold Buster, Boston, Mass. (Age 22, b. Boston, Mass.) Is a senior at Northeastern University. Has worked summers for Highway Division, Massachusetts Department of Public Works. Refers to H. B. Alvord, C. S. Ell, J. W. Ingalls, W. E. Nightingale.

Hampe, Fritz F., Jamaica Plain, Mass. (Age 25, b. Boston, Mass.) Is a junior at Northeastern University. During the work periods at the

University has worked for Aspinwall & Lincoln as rodman. Refers to H. B. Alvord, C. S. Ell, W. E. Nightingale.

Hilton, Henry B., Danvers, Mass. (Age 20, b. Danvers, Mass.) Is a junior at Northeastern University. During the work periods at the University has been connected witn F. W. Stowers, C.E., Methuen, Mass. Refers to H. B. Alvord, C. S. Ell, W. E. Nightingale.

Kepner, Harold Raymond, Boston, Mass. (Age 29, b. Mount Hope, Ohio.) Graduate of Massachusetts Institute of Technology, 1920, with degree S.B. in sanitary engineering. In 1920 was assistant engineer with Sanitary District of Chicago; 1921, with Illinois State Department of Health; 1922, with Providence Water Supply Board; 1923, assistant, and in 1924 instructor at Massachusetts Institute of Technology. Refers to J. B. Babcock, H. L. Bowman, K. C. Reynolds, C. M. Spofford, Hale Sutherland, F. E. Winsor.

McKenna, George Albert, Waltnam, Mass. (Age 20, b. Waltham, Mass.) Is a student at Northeastern University. Refers to H. B. Alvord, C. S. Ell, J. W. Ingalls, W. E. Nightingale.

Melcher, George Henry, Salem, Mass. (Age 19, b. Salem, Mass.) Graduate of Salem High School and now a student at Northeastern University. Refers to H. B. Alvord, C. S. Ell, J. W. Ingalls, W. E. Nightingale.

Nelson, Carl Harold, Dorchester, Mass. (Age 22, b. Sweden.) Graduate of West Roxbury High School in 1920; now taking civil engineering course at Northeastern University. During work periods has been employed by Walter Baker & Co. and Hartley L. White. Refers to H. B. Alvord, C. S. Ell, J. W. Ingalls, W. E. Nightingale.

Rubin, Morris, Roxbury, Mass. (Age 21, b. Boston, Mass.) Graduate of Boston English High School, 1921, and at present a student at Northeastern University. During work periods has been employed by C. L. Gannet as rodman, as transitman in town engineer's office at Belmont. Refers to H. B. Alvord, C. S. Ell, J. W. Ingalls, W. E. Nightingale.

Sawin, George Washington, Dorchester, Mass. (Age 19, b. West Newton, Mass.) Is a student at Northeastern University. Refers to H. B. Alvord, C. S. Ell, J. W. Ingalls, W. E. Nightingale.

Semenyna, Waldimir, Boston, Mass. (Age 22, b. Austria-Hungary.) Graduate of Rice Elementary and Mechanic Arts High School. Worked two years with Aspinwall & Lincoln during work periods while in school. Worked, for one year, 1922, with United Fruit Company in Puerto Castilla, and returned in 1923 to Northeastern University. Refers to H. B. Alvord, C. S. Ell, J. W. Ingalls, W. E. Nightingale.

Shepherd, Chester Davis, Everett, Mass. (Age 22, b. Everett, Mass.) Is a senior at Northeastern University. During work periods has been employed by Thomas Appleton, C. H. Gannett, John Dyer, New England Structural Company, and is now with John Dyer, Melrose. Refers to H. B. Alvord, C. S. Ell, J. W. Ingalls, W. E. Nightingale.

Simonds, Lermond Fales, Auburndale, Mass. (Age 21, b. Auburndale, Mass.) Has had two years at Massachusetts Institute of Technology, now on two years' leave, expiring October, 1925. June, 1923, to April, 1924, in field office of H. P. Converse & Co., constructing foundations for Bronx Terminal Market, New York City; May, 1924, to June, 1924, engineer on foundation of Dining Hall Building, Kent School, Kent, Conn.; in June, 1924, was appointed assistant engineer in the water division of the Metropolitan District Commission, to act as inspector of 60 inch steel pipe line of Weston Aqueduct supply mains. Refers to Clifford Foss, W. E. Foss, D. P. Kelley.

URQUHART, JAMES WALTER, Waltham, Mass. (Age 21, b. Waltham, Mass.) Is a student at Northeastern University. During work periods has had practice with R. H. Barnes & H. F. Beals, civil engineers. Refers to H. B. Alvord, C. S. Ell, J. W. Ingalls, W. E. Nightingale.

VERTIC, JOHN JOSEPH, Lawrence, Mass. (Age 21, b. Newmarket, N. H.) Graduate of Lawrence High School in 1922; now a student at Northeastern University, class of 1926. Refers to H. B. Alvord, C. S. Ell, J. W. Ingalls, W. E. Nightingale.

WOLFRUM, CARL ADAM, Boston, Mass. (Age 19, b. Roxbury, Mass.) Is a student at Northeastern University. Refers to H. B. Alvord, C. S. Ell, J. W. Ingalls, W. E. Nightingale.

For Transfer

HOUSER, GEORGE CROUSE, Marblehead, Mass. (Age 26, b. Akron. Ohio.) Graduate of Harvard College in 1920 with degree of A.B., received degree of S.B. in Sanitary and Municipal Engineering in 1922 from Harvard Engineering School. From October, 1922, to August, 1923, was assistant in zoning with the Boston City Planning Board; since August, 1923, has been with the Massachusetts Department of Public Health, where he is at present assistant sanitary engineer. Refers to F. L. Flood, H. E. Holmes, H. J. Hughes, A. D. Weston, G. C. Whipple, Edward Wright.

LIST OF MEMBERS

Additions

Lassiter, Richard T. . . 261 Edgecombe Ave., New York, N. Y.

Changes of Address

Alcott, William J., Jr. . . . 91 Chestnut St., Everett, Mass.
Bowers, George W. . . . 1603 So. 21st St., Birmingham, Ala.
Brown, C. Leonard . . . 1316 Euclid Ave., N. W., Apt. No. 4, Washington, D. C.
Danforth, George C. . . . . . 27 Weston St., Augusta, Me.
Kidd, Alexander L. . . . 1 Sea View Ave., Marblehead, Mass.
McCurdy, H. S. R. . 223 Savin Hill Ave., Upham's Corner, Mass.
Mirick, George L. . . 1 Baker Ct., P. O. Box 1458, Cincinnati, O.
Mulcare, Thomas . . 414 Mt. Auburn St., Cambridge, Mass.
Haley, F. W. . . . 2 Franklin Terrace, Melrose Hlds., Mass.
Parker, Burton C. . . . . 14 Batavia St., Boston, Mass.
Parsons, Alfred D. . . 4 Middletown Ave., Wethersfield, Conn.
Thompson, Walter L. . . . . 40 Lambert St., Medford, Mass.
Toole, Cameron S. . . . . . Box 18, Russell, Mass.
Tyler, Richard G. . . 1-153 Mass. Inst. Tech., Cambridge, Mass.

LIBRARY NOTES

Book Review

"Structural Engineering — Strength of Materials," by George Fillmore Swain, Gordon McKay Professor of Civil Engineering, Harvard University. First edition. McGraw-Hill Book Company, Inc., New York. 570 pages.

Reviewed by Lewis E. Moore*

For a number of years Professor Swain has given to his students mimeograph notes which have been used as texts in his courses. He has at last snatched the time from a very busy life as an engineer and teacher to expand and rewrite them entirely in permanent book form.

His work on "Structural Engineering" will comprise four volumes, of which the first two are complete. The first one, on "Strength of Materials," is the one under review.

There are many books on structural engineering and more books on strength of materials. Most of them approach the subject by laying down certain laws which have been discovered regarding the behavior of materials, and then derive mathematically the usual more or less well-known formulas for practical use. The result has too often been that students of these books have regarded the formulas as the final word and have applied them blindly, without regard to the limitations and other uncertainties of the experiments and data from which the laws were deduced, and without regard to the extent of their applicability. No one who studies this book could find the least excuse for such blind and slavish adherence to any of the formulas which are deduced therein. Professor Swain has used mathematics very freely, but has kept it in its proper position as a tool to aid reasoning, has always kept carefully to the fore the assumptions and limitations in the data, and has carefully avoided the introduction of mathematical juggling merely for the sake of swimming through a sea of integral signs and coming up on the other shore with a result that is supposed to be applicable *per se* under all sorts of conditions to all sorts of materials.

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* Consulting Engineer, 73 Tremont Street, Boston Mass.

The philosophy of the subject has been emphasized throughout and great care has been taken not only to state clearly what the laws governing the behavior of materials have been discovered to be, but also to state within what limitations of experiment or reasoning these laws can be logically expected to hold true, and the uncertainties underlying the assumptions upon which the various formulas commonly used are based.

In the brief space of a book review it is not possible to touch as fully as is desirable on the many excellent and unusual matters included. The review would be incomplete without mentioning more particularly such passages as the foot note on page 187: "It is important that the reader should acquire the habit of interpreting all algebraical expressions — otherwise they remain mere abstractions or combinations of letters in his mind, and he fails really to grasp them."

The treatment of actual distribution of normal strain and stress is most illuminating and makes very clear the actual conditions and the errors that one may easily fall into, even though he may think that he understands the subject thoroughly.

As an instance of the manner of treatment of the subjects it is to be noted that in riveted joints he carefully points out that lap joints actually are stronger than blind application of certain theories might indicate. In columns especially clear treatment is given of the interpretation, applicability and reasonableness of all the formulas.

The chapters on initial stresses and causes and conditions of failure are very unusual in a book of this character, and, further, are very unusual in themselves, both in their subject matter and the clarity of their treatment.

The first chapter is introductory and the second chapter gives a very brief review of the most essential principles of mechanics. The third chapter treats of certain geometrical relations which are not as a rule readily found gathered together, but for which the engineer has an almost constant use.

The next chapter treats of stress and strain and the behavior of materials under loads, expounding the different properties of solid bodies, modulus of elasticity, Poisson's Ratio, changes of volume produced by stress, allowable stresses, relation between stress and strain and its effect on the different properties with reference more particularly to the uses to which the metal is to be put, etc.

The next four chapters treat of the relations between stresses and between strains at a point on different planes passing through that point; pure tension and compression; shear; and torsion.

The ninth chapter takes up "The Inner Forces," or the distribution of normal stress on a section. A chapter on flexure, or the theory of stress in beams, follows. In this chapter slope and deflection of beams due to bending and shearing forces are discussed, together with the principles which govern the distribution of stress and strain both for homogeneous and non-homogeneous beams.

The eleventh chapter treats of shears, moments and influence lines, giving the principles underlying the finding of shears and moments and the construction and use of influence lines.

The next chapter treats of slope and deflection of beams in pure flexure. Four methods are given, all for finding slope and deflection. A number of different cases are worked out completely, showing the application of all four methods and the identity of results produced by them, also incidentally indicating which method is simpler in a given case, and clearly indicating the limits of the various processes.

The chapter on combined stresses follows, giving exact and approximate methods of solving various problems, together with some examples from practical cases. The chapter closes with certain remarks about combined stresses and specifications regarding them. The closing paragraph of the chapter is so characteristic of the comments made throughout the book that it is here quoted in full.

> This specification is of course inaccurate, as any such specification must be, but it is definite. If specifications are to be used and followed, they should be definite, even if wrong, for an error may be corrected, while an ambiguity cannot be interpreted, unless one party has power to decide on the interpretation, in which case it is only fair that he should state his interpretation and make the specifications definite, in order that the other party

to the contract may know what to expect. Many engineers, however, prefer to have this matter vague, perhaps because they are not clear on it themselves, but do not like to say so.

The next chapter on continuous and cantilever beams is followed by chapters on reinforced concrete beams and riveted connections.

The chapter on columns is especially noteworthy for its presentation and discussion of all the types of formulas that are in use, and the careful discussion of these different formulas with reference to their underlying assumptions and their applicability under different conditions.

Hollow cylinders, both thin and thick, are treated briefly, and are followed by chapters on testing of materials and repeated stresses and fatigue.

It is especially noteworthy that the book includes chapters on initial stresses in materials, causes and conditions of failure of a material, and closes with a chapter headed "Mathematics, Testing and Common Sense."

It is carefully kept before the reader throughout the whole book that the philosophy and logic of the subject are what must be considered first; in other words, the physical and philosophical side as distinguished from the purely mathematical. Mathematics are used very considerably, not as an end but as a means, and perhaps the author's attitude towards it can be indicated no better than by quoting from the last chapter: "Just as there is no vice worse than excessive or misapplied virtue, so there is no engineering mistake worse than excessive or misapplied mathematics, though many people seem to think that there cannot be an excess of it." He goes on to point out that the danger in the use of mathematics is that the machine itself is so interesting that attention will be concentrated upon it and diverted from the data, which are really the more important, and which actually define and control the accuracy of the result. He further points out that merely because mathematics is in itself accurate, many think that the results of mathematical investigations must be true, even though the data to which the mathematics is applied are incorrect. The author quotes John Stuart Mill as follows, that applications of mathematics should be studied "in such a manner that the intellect is aware of what it is about, and does not go to sleep over algebraical symbols."

The author then goes on to say that all this is no criticism of mathematics, but is merely a caution against its misuse and a criticism on the manner in which it is frequently taught and studied. He also pays his respects to the modern tendency to test everything, and points out that very often a test is merely a mentally lazy way of arriving at a result which might be reached more accurately by logical processes of thought.

The book is a remarkable one, both for the immense amount of ground which is covered in a comparatively brief space and the clearness with which underlying principles are emphasized. Professor Swain not only thinks clearly and logically, but is also the possessor of a happy faculty of succinct, and at the same time clear and unmistakable, language. When to this is added the ripe fruits of over forty years of combined teaching and engineering experience, the result is bound to be well worth while. The reader is led along the processes of logical thought and deduction, and not through an endless realm of mathematical symbols, although the careless or superficial reader might think the latter from the appearance of some of the pages. The usual aridity of presentation of this subject is largely avoided, and is further relieved by continual common-sense comment and occasional flashes of that trenchant humor of which the author is master.

If one accepts the definition of a treatise to be "a work intended to supersede thought on the part of the student," this book does not come under that head. To read it understandingly, one must read and reflect. As a text, the reviewer would not recommend it either to a lazy student or to a lazy teacher, but to one who is willing to read and study thoughtfully, no better presentation of the subject can be found.

The author has followed a very unusual course in presenting various plausible and more or less current theories and then showing why they are fallacious. In this he has evidently been actuated by the belief that one ought not only to know the true, but also the false, in order that one may distinguish between them and may not be confounded by the sudden production of a plausible theory which cannot readily be controverted on the spur of the moment. Throughout the book the author has not hesitated to express his own opinions, which gives the book a very human touch and adds materially to its interest.

The book is really a great addition to engineering literature, and although primarily a text, it brings out so clearly underlying principles and the limitations of our knowledge that no engineer who deals with strength of materials in any way can afford to be without it.

RECENT ADDITIONS TO THE LIBRARY

U. S. Government Reports

Geodetic Operations in United States and Outlying Possessions. 1922–23.

Results of Spirit Leveling in Maine, New Hampshire and Vermont.

Water Supply Papers, Nos. 517 and 521.

State Reports

New Jersey. Annual Report of State Department of Health. 1923.

New York. Annual Report of State Department of Health. 1922.

Municipal Reports

Lowell, Mass. Annual Report of Water Works. 1923.

Taunton, Mass. Annual Report of Water Commissioners. 1923.

Miscellaneous

Accounting and Business Methods for Contractors. Chas. F. Dingman. Gift of Author.

Engineering Economics. John C. L. Fish.

Structural Engineering. Vol. 1. Strength of Materials. George F. Swain. Gift of Publisher.

Structural Engineers Handbook. 1924 Edition. Milo S. Ketchum.

Tulley's Handbook, Steam and Electrical. 3 volumes. A completely revised edition.

LIBRARY COMMITTEE.

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FOUNDED 1848

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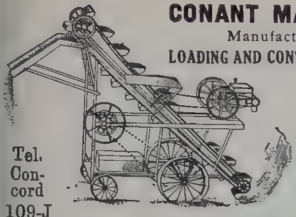

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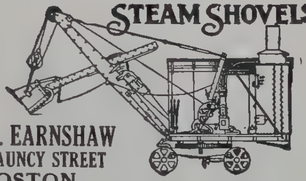

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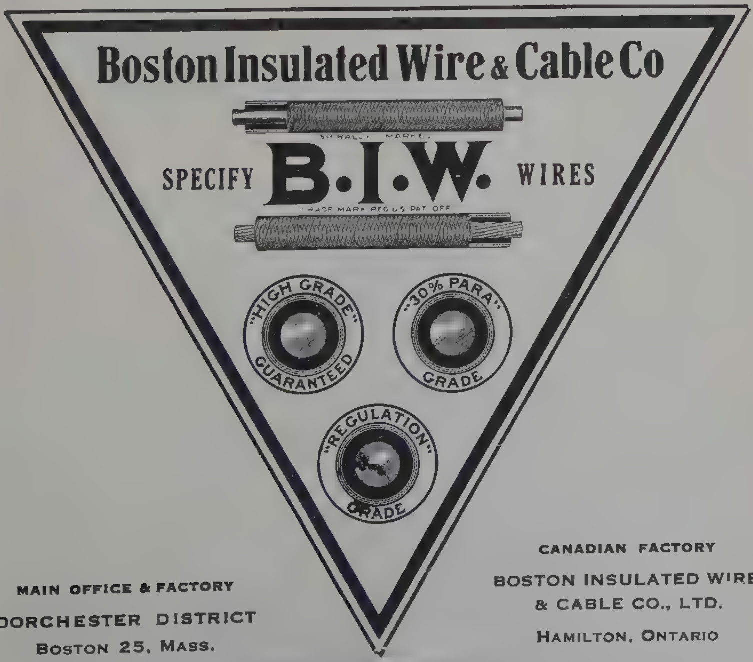

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